# MINISTRY OF WATER AND IRRIGATION

## Water Resource Policy Support

*GROUNDWATER MANAGEMENT COMPONENT*

# GROUNDWATER MANAGEMENT ACTION PLAN FOR THE AMMAN–ZARQA BASIN HIGHLANDS

**July 12, 2001**

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## ABBREVIATIONS

| | |
|---|---|
| AZB | Amman–Zarqa Basin |
| ECC | Economic Consultative Council |
| Fil | Unit of currency, equals 1/1,000 of a JD |
| GMCC | Groundwater Management Consultative Committee |
| GMF | Groundwater Management Fund |
| GPS | Global Positioning System |
| GIS | Geographic Information System |
| HDH | Hashmiyah–Dulayl–Hallabat |
| IAS | Irrigation Advisory Service |
| JD | Jordanian dinar (currency) |
| JICA | Japanese International Cooperation Agency |
| JV | Jordan Valley |
| JVA | Jordan Valley Authority |
| $km^2$ | Square kilometers |
| KTR | King Talal Reservoir |
| MCM | Million Cubic Meters |
| $m^3$ | Cubic Meter |
| M&I | Municipal and Industrial |
| MOA | Ministry of Agriculture |
| MWI | Ministry of Water and Irrigation |
| NCARTT | National Center for Agricultural Research and Technology Transfer |
| NGO | Non-governmental Organization |
| O&M | Operations and Maintenance |
| RA | Rapid Appraisal |
| RS | Remote Sensing |
| TO | Task Order |
| UFW | Unaccounted for Water |
| USAID | United States Agency for International Development |
| WAJ | Water Authority of Jordan |
| WRPS | Water Resource Policy Support |

# EXECUTIVE SUMMARY

This final groundwater management action plan presents practical options for reducing the current overabstraction of Amman–Zarqa Basin (AZB) highlands groundwater resources. The plan was developed with full cooperation of the Ministry of Water and Irrigation (MWI), water users, and related government and private institutions.

## Groundwater Resources and Water Use

AZB aquifers have the highest groundwater recharge (88 million cubic meters, or MCM, per year) in Jordan, and represent about 30% of the nation's renewable groundwater resources of 275 MCM/year. A significant part of the recharge is groundwater inflow from Syria, with the remainder accounted for by local rainfall and intermittent runoff. Around 70 MCM, or 80% of the total AZB groundwater renewable resource, are in the Basalt and the B2/A7 aquifers, which are located in the northeastern highlands extending north to the Syrian border and southwest to the outskirts of Amman over approximately 2,420 $km^2$.

Groundwater abstraction in the AZB exceeded safe yield (88 MCM) by 55% in 1989, increasing to over 70% (150 MCM) in 1998, according to MWI database information. The bulk of pumping (125 MCM) occurs in the highlands, with 48% for irrigation, 46% for domestic supply, 4.5% for industrial, and for 1.5% pastoral. Nearly 90% of AZB irrigation water use is in the highlands. By 2002, overabstraction in the AZB highlands will reach nearly 100% with the development of the new Corridor wellfield located North of Hallabat, which is planned to supply an additional 10 MCM for Municipal and Industrial (M&I) purposes.

## Overabstraction Impacts

During the last two decades, overpumping has resulted in significant water level decline and salinity increase in the Dulayl area, drying up of springs near Sukhna, and reduced water level and water quality in parts of North Badiya. Results of the groundwater modeling study indicate that continued overpumping of groundwater in the AZB highlands over the next 20 years is projected to deteriorate groundwater quality, with drawdowns averaging 0.5 meters per year and drying up of 70% of the wells in the Hashimiya–Dulayl–Hallabat (HDH) area. As a result, the agricultural sector in the AZB highlands is expected to incur a total of JD52.65 millions in losses over the next 20 years. These losses are distributed as follows:

- JD5.90 millions increase in energy cost for pumping owing to drawdowns;
- JD5.05 millions for well deepening and reconstruction;
- JD18.20 millions investment losses owing to abandonment of 74 farms, as a result of drying up of 70% of the wells in the HDH area; and
- JD23.5 millions in crop yield losses owing to salinity.

The abandonment of 74 farms in the HDH area would also lead to a total labor loss of 2,015 jobs, including 594 male foreign, 660 male local, and 851 female local. This translates to a 4.5–4.7% increase in the local unemployment rate in the AZB highlands, which is currently around 15%. Farm input/output related services such as pesticide and fertilizer companies, transportation, food processing, and marketing sectors would lose around 30 jobs.

Depletion of water resources, deterioration of water quality, soil salinity that may lead to soil sterility, and reduction of green spaces owing to abandonment of farms are the main environmental problems foreseen as a result of the continued groundwater overexploitation.

## Development of a Management Action Plan

### *Objectives*

Given the current shortages of domestic water supplies and the importance of this high priority sector, moving toward a more sustainable water use trajectory in the AZB highlands requires reducing the use of groundwater for irrigated agriculture. The main objectives of the groundwater management component activity of the Water Resource Policy Support (WRPS) Task Order (TO) are:

- The exploration of practical options for reducing groundwater use in the irrigated AZB highlands and
- The development of an action plan to support the implementation of these options, moving toward a sustainable abstraction from the highland aquifers.

### *Exploring management options: A participatory approach*

It is widely recognized that the reduction of agriculture water use in the highlands is a politically difficult and challenging task (WRSP Scope of Work, August 1999). Consequently, the strategy followed in the accomplishment of this task is based on full participation of MWI, water users, and other relevant stakeholders in the exploration of management options and the development of this action plan.

A Rapid Appraisal (RA), which was conducted during April–June 2000 in the AZB highlands, provided technical and socioeconomic information on water use and users. It also initiated a participatory water management process by exploring water users' ideas and suggestions on options and practical actions for groundwater use reduction, and on the willingness to replace groundwater abstraction with recycled water. Field interviews were completed for 155 farms and 170 wells, out of a total of 367 irrigation wells currently operating in the AZB highlands. Groundwater management interviews were successfully completed with 80 owners, and eight small group meetings were held with community leaders and farm owners. This high level of participation was considered unlikely at the beginning of the survey, and reflects the interest of farmers in future decisions related to groundwater management in the AZB highlands. Findings of the RA, the profile of water use and users, and recommendations on groundwater management in the AZB highlands were reported in the "Study of Water Use and Users in the Northeastern Amman-Zarqa Basin" (MWI/ARD, January 2001). The RA also presented valuable insights to MWI decision-makers, and opened doors to a collective effort in conserving AZB groundwater resources.

***Management options***

Following the RA work and discussion with MWI and other stakeholders the following five reduction options are identified and presented in the attached Summary table.

- Irrigation Advisory Service (5 MCM/year estimated reduction);
- Wells buy-out (15–20 MCM/year);
- Enforcement of abstraction limit (10–15 MCM/year);
- Exchange of groundwater with treated wastewater (15 MCM/year: 10 MCM for irrigation and 5 MCM for industrial use); and
- M&I reduction: 30 MCM, with 10 MCM as regained unaccounted for water (UFW) resulting from reduction of physical losses owing to rehabilitation of water conveyances and M&I water use saving by reducing water wastage by big industries, hotels, and households; and 20 MCM replaced by new water supplies from Disi, Wehda, Zara–Main, and AZB brackish water sources

***Management scenarios***

The identified groundwater use reduction options were grouped in four scenarios representing possible ways to implement these options. These scenarios were designed to assist decision-makers and stakeholders to move gradually toward a sustainable abstraction from the highland aquifers, starting with a minimum reduction for scenario 1 and progressing to a maximum reduction for scenario 4. Scenarios 1 and 2 include three irrigation water use reduction options—namely, Irrigation Advisory Service (IAS), wells buy-out, and enforcing abstraction limits. Scenario 1 corresponds to a reduction of 30 MCM, which consists of 5 MCM IAS, 15 MCM buy-out, and 10 MCM enforced abstraction limit. Scenario 2 has a 40-MCM reduction corresponding to the maximum reduction of each of the three irrigation use options. Scenario 3 corresponds to a 55-MCM reduction, which encompasses the options of scenario 2 in addition to the 15 MCM of reuse option. Implementation of scenario 4 would result in a sustainable abstraction from the highland aquifers by considering the M&I reduction to reach the 70-MCM safe yield abstraction. Thus, scenario 4 would correspond to a total reduction of 85 MCM, including all options in scenario 3 in addition to 30 MCM M&I reduction.

***Assessment of management options and scenarios***

Each of the above options was legally, economically, and socially assessed. Other activities were also carried out to support the analysis and screening of management options and scenarios, including assessment of irrigation practices and IAS needs; quantification of water use and remote sensing studies; groundwater modeling to analyze impacts of overpumping; a study of brackish water potential and other sources of water resources augmentation; and capacity building in groundwater modeling and remote sensing.

On the basis of the above assessments and further discussion with stakeholders, a draft preliminary action plan was prepared in April 2001. The plan presented a detailed characterization of each option, indicating the level of priority of each option and its level of cost and difficulty of implementation; legal coverage; institutional responsibility; socioeconomic impacts; and proposed actions to support implementation. The options priorities and assessment are in the Summary table.

| Groundwater Management: Summary of Results from Options Assessment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Description of Option** | **Expected Reduction (MCM/year)** | **Ranking of Overall Priority** | **Ranking According to Least Cost** | **Ranking According to Least Difficulty** | **Expected Benefits** | **Legal Aspects** | **Institutional Responsibility** | **Disadvantages** |
| Irrigation advisory | 5 | 1 | 1 | 2 | -JD3000/well (energy)<br>-Increase in production<br>-GW conservation<br>-Durability of M&I supply | Indirectly covered | MWI & MOA | Difficulties of institutional establishment and sustainability |
| Wells Buyout | 15–20 | 1 | 3 | 1 | -GW conservation<br>- Durability of M&I supply | Covered in WAJ Law and suggested Bylaw. | MWI & WAJ | Unemployment and associated impacts |
| Limiting abstraction and/or cropped area | 10–15 | 1<br>3 | 2 | 3 | -GW conservation<br>-Durability of M&I supply | Covered in WAJ Law and suggested Bylaw. | MWI, WAJ, MOA | Needs intensive monitoring and management |
| Exchange groundwater with recycled water | 15 (10 for irrigation and 5 for industrial) | 1 | 4 | 2 | -GW conservation<br>- Durability of M&I supply | Not directly covered in WAJ Law or Bylaw, but mentioned in (wastewater policy document-1998). | MWI, WAJ, MOA | Cropping pattern changes<br>Public health and environmental concerns |
| M & I pumping reduction | 30<br><br>(10 UFW and M&I Water use saving, 20 replaced by other supply sources such as Disi–Wehda, brackish water) | 2 | 5 | 4 | -GW conservation<br>- Durability of M&I supply | Not directly covered, but articles in the Law or Bylaw deal indirectly with this issue. | MWI & WAJ | Difficult to implement, given high priority of municipal demand and dependability on implementation of other water supply projects such as Disi and Wehda dam |

***Supporting Actions***

A series of recommended actions to support the implementation of the management options and scenarios are presented according to their priority. These recommended supporting actions include the enforcement of interdiction of illegal drilling; amendment of water use and management-related laws and regulations; institutional reform and integrated basin level management; stakeholder participation and formation of a groundwater management consultative committee; marketing, monitoring, and information management; and water user education and public awareness. Also discussed are alternative options for improving water supplies such as brackish water exploration and development to augment water supply and recharge, and water harvesting to increase water resources in the AZB.

To overcome the overlap of institutional responsibility for implementation of the groundwater use management options, and concerns about the sustainability of the IAS and funding of incentives for implementation of difficult options such as reduction of abstraction limits, the Groundwater Management Consultative Committee (GMCC) and Groundwater Management Fund (GMF) are recommended as implementation support tools designed to ease these constraints.

The GMF would support the sustainability of the IAS and operation of the well metering program, and would provide incentives related to the implementation of the groundwater use reduction action plan. This fund can be generated from water conservation fees from M&I and agricultural use, water charges from private industrial wells, and overabstraction charges from agricultural water users. A preliminary estimate of GMF income is expected to be approximately JD2.5 millions/year.

***Stakeholders Discussion of Action Plan***

A one-day stakeholders meeting was held on 11 June 2001, to further discuss with stakeholders and screen the various groundwater management options and scenarios, and the practical actions to support their implementation. The meeting involved more than 80 participants, including community leaders, specific farmers, the Head of the National Farmers Union and its representatives in the AZB and Jordan Valley, farm managers, representatives of the Governorate of Mafraq, government agencies, and independent institutions. Two groundwater-working groups were formed to discuss the five selected options, the GMF, and the GMCC. All five management options were endorsed. Concerns about social and environmental (desertification) impacts of buy-out, socioeconomic and environmental impacts of limiting abstraction, and impacts of water reuse on marketing and environment were expressed. The GMCC and GMF were strongly supported. Among the suggestions for implementation of the action plan made by the groundwater-working groups were (1) establishing alternative activities and projects for those who opt for well buy-out, (2) ensuring fair buy-out, (3) elaborating clear legislation to support GMF, and (4) promoting water harvesting.

On the basis of the above results, it is concluded that the groundwater management plan has provided the practical options for reducing groundwater use in the AZB highlands through a joint effort with MWI, the water users, and other relevant stakeholders.

## ACKNOWLEDGMENTS

This groundwater management action plan was written by Mohamed Chebaane with the support of Lana Naber, Kamel Radaideh, and Ahmad Abu Hijleh and inputs from a number of international and local specialists whose efforts are documented in the supporting studies. Special thanks are extended to Tom Cusack for his valuable support and assistance.

The effort and contribution of MWI colleagues in developing this plan and in being actively involved in the supporting studies are highly appreciated. We are particularly indebted to the support of H.E. Dr. Hazim El Naser, the Minister of Water and Irrigation and Eng. Fayez EL Bataineh, Assisting Secretary General of MWI. We are also extremely grateful for the valuable participation of Eng. Edward Qunqur, Director of Water Resources Directorate; Eng. Suzan Taha, Director of MIS Directorate; Mr. Mohammad Almomani; Dr. Rakad Ta’any; Mr. Salameh Al Khureisheh; Eng. Ali Subah; Mr. Nidal Khalifah; and Mr. Jihad Al Abadi.

The valuable assistance of Dr. Khair Hadidi, Head of well permitting at WAJ; Mr. Anwar Na’im, from WAJ; Eng. Waleed Sukkar, head of Unaccounted for Water Projects at WAJ; and Naif Sedar, Head of IAS at JVA, is also highly appreciated.

Special thanks and appreciation are extended to AZB highlands farmers and community leaders for being actively engaged in exploring and discussing groundwater use reduction options. Their input was instrumental and crucial in the development of this plan.

The cooperative efforts of the Ministry of Agriculture technical staff, a representative of Mafraq Governorate, and members of the Irrigation Committee of the Economic Consultative Council are very much appreciated.

Finally, the support of the United States Agency for International Development Mission in Jordan and the ARD, Inc. team, in Jordan and Vermont, is highly appreciated.

# 1. INTRODUCTION

The main objectives of the groundwater management component of the Water Resource Policy Support (WRPS) Task Order (TO) are (1) The exploration of practical options for reducing groundwater use in the irrigated Amman–Zarqa Basin (AZB) highlands and (2) The development of an action plan to support the implementation of these options and moving toward sustainable abstraction from the highland aquifers.

The AZB extends from Jebel Arab in Syria in the northeast, the Rift Side Wadis basin in the west, Yarmouk basin in the northwest, Azraq basin in the east and south, and to the Dead Sea basin in the southwest (Figure1).

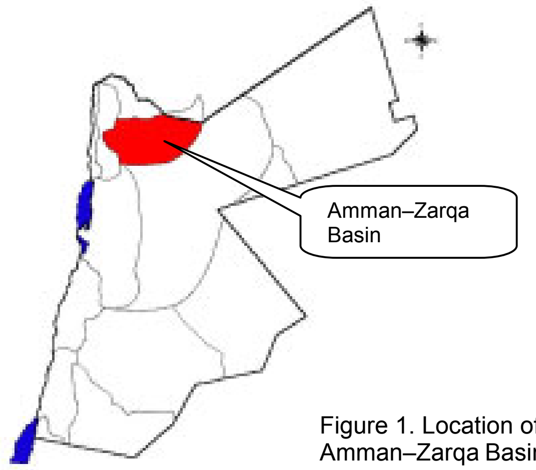



Figure 1. Location of Amman–Zarqa Basin

AZB covers a total area of 4,586 square kilometers ($km^2$), with about 4,074 $km^2$ in Jordan and 512 $km^2$ in Syria, and includes the country's largest urban agglomeration and major industrial sites and irrigated areas.
Amman–Zarqa aquifers have the highest groundwater recharge (88 million cubic meters, or MCM, per year) in Jordan and represent about 30% of the nation's renewable groundwater resources of 275 MCM/year. A significant part of the recharge is groundwater inflow from Syria, with the remainder from local rainfall and intermittent runoff. Around 70 MCM, or 80% of the total AZB groundwater renewable resources, are in the Basalt and the B2/A7 aquifers, which are located in the northeastern highlands extending north to the Syrian border and southwest to the outskirts of Amman over approximately 2,420 $km^2$. The boundaries of the northeastern highlands are defined herein as the limits of the geographical area, within the Jordanian side of the Amman–Zarqa groundwater basin, where the B2/A7 aquifer system is saturated (Figure 2). Note that, hereafter, the northeastern highlands are simply referred to as "highlands."

Groundwater abstraction in the AZB exceeded the safe yield of 88 MCM by 55% in 1989. By 1998, abstraction had increased to around 150 MCM, representing 170% of the safe yield, according to MWI database information (Figure 3). The bulk of pumping (125 MCM) occurs in the highlands, with 48% for irrigation, 46% for domestic supply, 4.5% for industrial, and 1.5% for pastoral. Nearly 90% of AZB Irrigation water use is in the highlands (Figure 4). Overpumping has resulted in significant water level decline and salinity increase in the Dulayl area, drying up of springs near Sukhna, and reduced water level and water quality in parts of North Badiya (Figure 5).

The Rapid Appraisal (RA), which was conducted in April–June 2000 in the AZB highlands, provided technical and socioeconomic information on water use and users. It also initiated a participatory water management process by exploring water users' ideas and suggestions on options and practical actions for groundwater use reduction and on the willingness to replace groundwater abstraction with recycled water. Findings of the RA, the profile of water use and users, and recommendations on groundwater management in the AZB highlands were reported in the "Study of Water Use and Users in the Northeastern Amman-Zarqa Basin"(MWI/ARD, January 2001). A summary of the RA findings is presented in Figure 6. The recommendations were legally assessed based on current water and agricultural laws and regulations. A socioeconomic analysis of these recommendations was completed. Other activities were also carried out to support analysis and screening of management options and scenarios. These activities include assessment of irrigation practices and Irrigation Advisory Service (IAS) need, quantification of water use and remote sensing (RS), groundwater modeling to analyze impacts of overpumping, a study of brackish water potential and other sources of water resources augmentation, and capacity building in groundwater modeling and RS.

A draft preliminary action plan was prepared in April 2001 and discussed with the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan (WAJ), and the Jordan Valley Authority (JVA) counterparts. A one-day stakeholders meeting was held on 11 June 2001 to further discuss with stakeholders and screen the various groundwater management options, scenarios, and the practical actions to support their implementation. The meeting involved more than 80 participants, including community leaders, specific farmers, the head of National Farmers Union and its representatives in the AZB and Jordan Valley, farm managers, representatives of the Governorates of Mafraq, government agencies, and independent institutions. A complete list of participants and the major outcome and recommendations of the stakeholders meeting are included in the report of the meeting (MWI/ARD, June 2001).

This report presents the discussed final action plan for groundwater management in the AZB highlands. This action plan includes a description of hydrogeologic and economic impacts of overpumping and a characterization of five groundwater use curtailment options based on their legal and socioeconomic assessment and on discussions with stakeholders. The plan also describes four management scenarios, which are developed based on priority-cost-difficulty of implementation of each option, and presents a series of recommended actions to support the implementation of the groundwater management options and scenarios.

# 2. IMPACTS OF CONTINUED OVERPUMPING

Prior to the characterization and evaluation of the potential practical groundwater management options, it is essential to analyze the various hydrological, socioeconomic, and environmental impacts if overabstraction continues uncontrolled at the current rate. This analysis is intended to enlighten decision-makers and water users in particular, as well as other relevant stakeholders about the gravity of the problem.

## 2.1 Hydrogeological Impacts

Hydrogeological impacts of overpumping are generally manifested in water table decline and increase in water salinity, which may also be due to irrigation water return. Both water level decline and salinity have been observed in the last decades in parts of the basin. In particular, water level has significantly declined and salinity has increased in the Dulayl area, springs have dried up near Sukhneh, and water levels and water quality have decreased in parts of North Badiya (Figure 7).

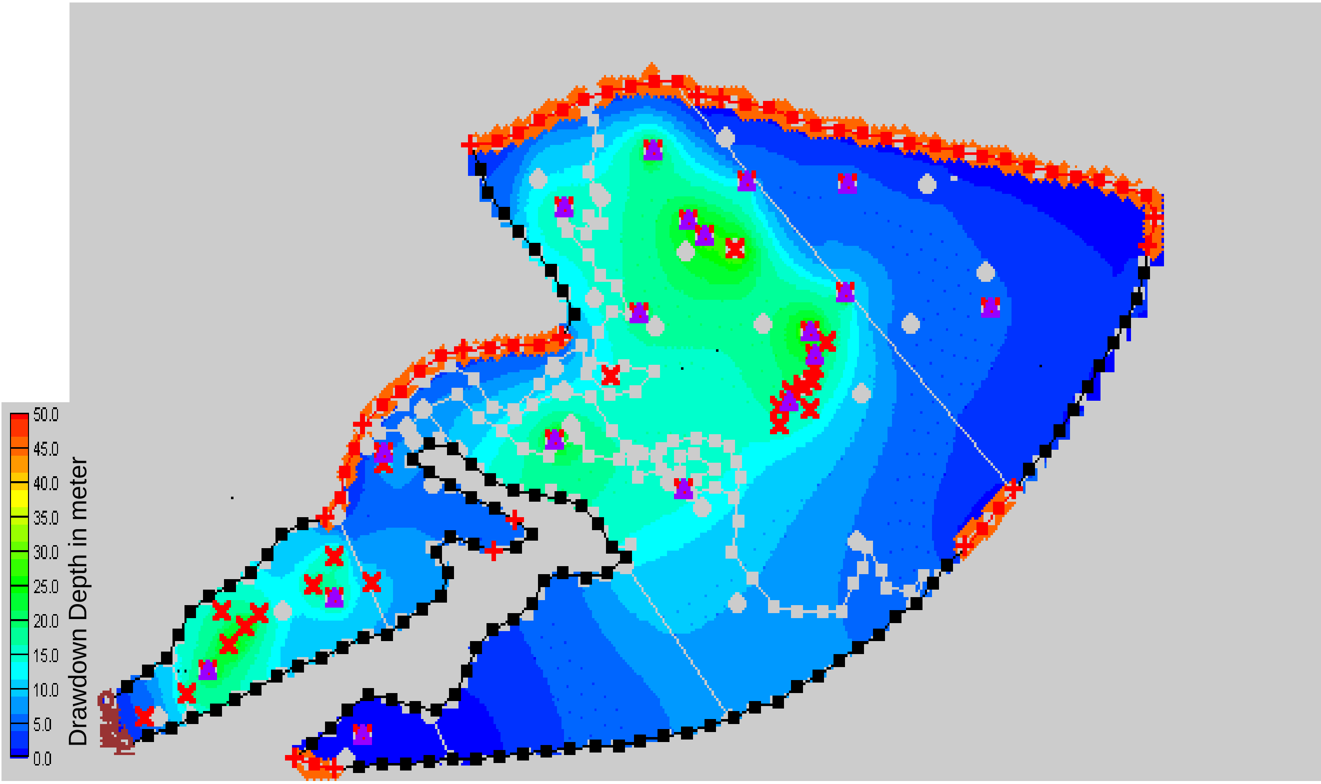
The results of the groundwater modeling study (MWI/ARD, May 2001) indicate that continued overpumping in the highlands area over the next 20 years is projected to lead to further decline of the water table and deterioration in groundwater quality. The model shows that, if abstraction is increased by 10 MCM by early 2002 owing to the start of production of the municipal corridor wells and continues at the total level of 155 MCM/year, the water table is expected to drop by an additional 10–30 meters in many parts of the aquifer (see Figure 7). The average of the drawdown projected over the next 20 years is around 0.5 meter/year. The model also shows that 70% of the wells (74 wells) in the Hashimiya–Dulayl–Hallabat (HDH) area are expected to dry up within the next 15 years, and the salinity levels will increase to the 1,000–5,000 ppm range in most parts of the basin.

## 2.2 Economic Impacts

Several different types of economic impacts can be anticipated from the decline in water table. All users will experience increased costs of energy, either electricity or diesel fuel, owing to water table decline. In some cases, the water table will decline beyond the reach of the existing well, and it will need to be deepened or reconstructed, which will cause the owners to incur significant costs. In areas where the aquifer goes dry, farms will be abandoned entirely, causing the value of the investment and any future earnings from the farm to be lost. Details about estimation of these losses are presented in the socioeconomic study (Jabbarin, April 2001). Figure 8 illustrates that the expected agricultural sector losses due to continuous overpumping over the next 20 years of the AZB highlands aquifers amount to a total of JD52.65 millions distributed as follows:

- JD5.90 millions increase in energy cost for pumping owing to drawdowns;
- JD5.05 millions for well deepening and reconstruction;
- JD18.20 millions investment losses owing to abandonment of 74 farms, as a result of the dry up of 70% of the wells in the HDH; and
- JD23.5 millions in crop yield losses owing to salinity.

**Figure 7 : Drawdown in 2020 as Result of Continuous Over-Pumping**



## 2.3 Social Impacts

The abandonment of 74 farms in the HDH will lead to a total labor loss of 2,015 jobs (594 male foreign, 660 male local, and 851 female local; see Figure 9). This translates to a 4.5–4.7% increase in the local unemployment rate in the AZB highlands, which is currently around 15%. In addition, labor losses incurred by farm input/output-related services is estimated at 30 jobs.

## 2.4 Environmental Impacts

Continuous overpumping is expected to cause four main environmental problems: (1) depletion of water resources, (2) deterioration of water quality, (3) soil salinity, which may lead to soil sterility, and (4) reduction of green spaces owing to abandonment of farms, and (5) fauna and flora in the impacted areas may be affected.

# 3. CHARACTERIZATION OF GROUNDWATER USE REDUCTION OPTIONS

The following practical options for groundwater use reduction in the AZB were identified and presented in the report of the "Study of Water Use and Users in the Northeastern AZB" (MWI/ARD, January 2001):

- IAS;
- Wells buy-out;
- Reduction of abstraction by limiting annual abstraction or limiting cropped area;
- Exchange of groundwater with recycled water; and
- Municipal and industrial (M&I) pumping reduction.

This section presents, for each option, the objective, level of priority, current situation, estimated groundwater use reduction, time schedule for implementation, and socioeconomic impacts.

## 3.1 Irrigation Advisory Services

- Objective: The aim of this activity is to increase irrigation efficiency by reducing overirrigation, and therefore reducing overpumping.

- Priority: Irrigation advisory is a first priority option.

- Current Situation: Rapid Appraisal (RA) field visits, conducted by MWI/ARD in April–June 2000, revealed that virtually all farms use drip irrigation. However, most farmers are not adequately using this modern irrigation method. Once vendors install the drip irrigation system, most farmers are left alone with little knowledge about its efficient use. Agricultural extension services are quasi-absent in the AZB highlands. As a result, irrigation water loss is expected to be high. Farmers are willing to be better informed about crop water requirement and water conservation methods. Nearly all of them, 97.9% in Mafraq and 100% in Zarqa (ARD, January 2001), are in favor of the establishment of an IAS. However, only a limited number of well owners are willing to pay for the service.

  Blane Hanson (MWI/ARD, August 2000) conducted an evaluation of the potential for an IAS program in the AZB highlands, to assist farmers in improving irrigation water efficiency. Data on groundwater pumping and field observation suggest that in many cases, considerable overirrigation is occurring (ARD, January 2001). The evaluation activity has confirmed that farmers have little knowledge about the performance characteristics of their irrigation systems, and recommended the establishment of an IAS in the AZB uplands. The August field visit was also an opportunity to involve farm owners in the evaluation of their irrigation systems, as part of the participatory management of AZB groundwater. Farmers were very much interested in the outcome of the evaluation, and five of them volunteered to offer experimental sites for a potential IAS pilot program.

- Estimated Reduction: According to Hanson (MWI/ARD, August 2000), IAS could result in water savings of 15–20%. Jordan Valley IAS results indicate that water consumption at the farm level can be reduced by an average of 20%

(JVA/USAID, 2000). On the basis of 60 MCM-irrigation water use in the AZB highlands, as indicated in the 1998 MWI database, and on an estimate of 20% IAS water savings, the potential reduction of applied irrigation water in the AZB highlands may reach 12 MCM. Preliminary assessments of metering data by the ARD groundwater management team indicate a higher value for AZB highlands irrigation water abstraction estimated at 80 MCM, compared with 60 MCM using the MWI database. This would result in a higher potential irrigation water savings that may reach 15 MCM, assuming no well buy-out and no crop area reduction. However, despite the IAS request by almost all farmers, we expect that some farmers will not apply IAS recommendations. A 10-MCM reduction via IAS seems to be more realistic. If 25–30% of irrigation wells are bought out and 30% of remaining cropped area reduction is achieved, the IAS savings will be limited to around 5 MCM.

- Expected Benefits: Based on 60 MCM of irrigation groundwater use (1998 MWI database) for 367 irrigation wells, the average pumping is approximately around 160,000 m3/year/irrigation well for the AZB highlands. The latter figure would increase to nearly 220.000 m3/year/irrigation well, given that the actual irrigation groundwater use in AZB highlands is around 80 MCM, according to ARD groundwater management team's estimation. For an average pumping energy cost of 70 Fils/m3, 20% reduction through IAS would correspond to an energy savings cost of approximately JD2,200 and JD3,100/well/year, respectively, for the 60- and 80-MCM estimates. In addition, reduction of overirrigation may increase yield (JVA/USAID, 2000). Thus, IAS is a viable incentive-based groundwater management tool that would assist farmers in reducing energy cost and increasing profitability.

- Legal Coverage: IAS is not directly covered by the existing law and proposed groundwater monitoring regulation (bylaw). However, since IAS is intended to reduce irrigation water consumption and enhance water conservation, Article 6 of the 1988 Water Authority Law, Article 7 of the proposed groundwater monitoring bylaw, and Article (3), Item (G), of the Agriculture Law No. (30) of 1973 and its amendments would apply to IAS.

***Article 6, 1988 WAJ law No. 18:***

***To achieve all the objectives intended by this Law, the Authority shall exercise the following responsibilities and tasks:***
***Survey the different water resources; conserve them; and determine ways, means, and priorities for their implementation and use.***
***Regulate the uses of water, prevent its waste, and conserve its consumption.***

***Article 7, proposed new groundwater regulation:***

***The drilling of public and private wells shall be supervised, the use of groundwater and the quantities abstracted shall be limited and monitored, and the consumption of groundwater shall be conserved on the basis of regulatory resolutions issued by the Council, based on the Minister's recommendation.***

***Item (G) of Article (3) of the Agriculture Law No. (20) of 1973 and its amendments:***

***The Minister of Agriculture is empowered with the specification of crop-farming methods, ratios of sowing seeds, types and ratios of fertilizers, and other agricultural services of irrigation and fertilization.***

- Implementation Responsibility: MWI and Ministry of Agriculture (MOA). Note that the MOA role in highlands agriculture extension is quasi-absent; this makes it difficult to conduct other extension services such as IAS. It is therefore recommended that IAS should be developed with the support of the private sector and water users. Discussions with drip irrigation equipment vendors in the highlands indicate that they are interested in being part of the IAS activity.

  Following the ongoing pilot IAS experience in the Jordan Valley, the government and donors, including the United States Agency for International Development (USAID) and the German Technical Cooperation, are discussing the establishment of an IAS in the highlands by financing pilot schemes and providing training. However, there are mainly two concerns about the implementation of the IAS. First is the lack of clear institutional responsibility, and the second is the concerns about the sustainability of the service after the pilot phase. Hanson (MWI/ARD, August 2000) suggested that a highlands IAS would be conducted by MWI in conjunction with the private sector. Scott and Hagan (January 2001) proposed the following options:

  - Restructure the JVA, amend the law, and enlarge the mandate to cover all irrigation in Jordan;
  - Move the IAS from JVA to the MWI; and
  - Establish an IAS within the
    - Ministry of Agriculture (MOA),
    - National Center for Agricultural Research and Technology Transfer (NCARTT),
    - Non-governmental Organizations (NGOs),
    - Educational institution, and
    - Private sector IAS.

  The above suggestions still face the two fundamental issues: the lack of clear institutional responsibility and concerns about the sustainability of the service after the pilot phase. The basin integrated management approach and Groundwater Management Fund (GMF), recommended hereafter as implementation support actions, are designed to ease the institutional and sustainability constraints. At the basin level, MWI, MOA, water users, and the private sector would operate by integrating MWI water expertise with MOA know-how on crop selection to fit soil and water quality parameters, and private sector (irrigation equipment vendors') experience in operation and maintenance (O&M) of modern irrigation methods. The GMF will assist in sustainability of the service by ensuring a durable source of funding for the IAS.

- Proposed Action Plan: Establish a five-year pilot IAS program in the AZB highlands run by three specialists:
  - Irrigation engineer from MWI: an IAS specialist transferred from JVA to the AZB highlands pilot program;
  - Irrigation engineer from a national irrigation equipment company, which operates in AZB highlands; and
  - Agricultural/Soil-water specialist from MOA, preferably from NCARTT.

  The pilot program will cover four test areas: a fruit farm, olive tree farm, and two seasonal crop farms.

***Time schedule***

The pilot activity is proposed to start in 2002 and continue up to 2006, with the objective of achieving the following water-savings target or irrigation water use reduction: 1 MCM in 2003, 2 MCM in 2004, 3 MCM in 2005, 4 MCM in 2006, and 5 MCM in 2007 and afterward (see Figure 10).

***Estimated cost***

Total estimated costs over the five-year period would be JD300,000, which cover salaries of the above-mentioned three qualified specialists, equipment, training, and vehicles.

***Economic impacts***

Valuing the water saved at the opportunity costs of JD0.424 (capital cost) per $m^3$, the present value of the water saved via IAS (5 MCM/year) over the next 20 years in this way comes to JD11.5 million. The opportunity cost of groundwater was defined as the government's cost to develop alternative sources of supply for Amman. Specifically, the estimated capital cost for the proposed Disi Conveyor Pipeline was used as the opportunity cost. Water from Disi is expected to cost JD0.424 per $m^3$, in annualized terms. This value may be lower than the true opportunity cost since it does not include any allowance for annual O&M costs (Fitch, April 2001). The JD300,000 estimated cost of implementing this service, to be spread over five years, is quite small in comparison. In present value terms, the cost would be only JD250,000—or only 2.2% of the present value of the opportunity cost. *Thus, IAS would be a highly attractive economical option.*

***Social impacts***

IAS will not engender labor losses or reduction of other services. Therefore, it has no negative social impacts.

***Environmental impacts***

IAS will have two positive environmental impacts. The first results from the fact that groundwater use reduction due to IAS will contribute to groundwater conservation. In addition, IAS is expected to reduce the amount of applied water, which in turn results in reduction of irrigation return that translates into a better protection of groundwater quality.

### 3.2 Wells Buy-Out

- Objective: The Government would buy out irrigation wells and close them down, with the objective of reducing overabstraction to conserve and protect AZB highlands' aquifers and assist mainly the durability of M&I water supply from these aquifers.

- Priority: This is a first-priority option.

- Current Situation: Farm ownership started mainly with Bedouins, since irrigated agriculture was developed to provide them with a reliable source of income to enhance social welfare and stability in the Badia. Some of the Bedouins sold their property rights after they got their well licenses. Others drilled their wells and sold their farms after failing to survive in the business. As a result, the pattern of farm ownership has shifted to private investors from outside the area, who own around 49% of surveyed Mafraq farms and 76% of those in Zarqa. Currently, many farm owners have financial difficulties because of deterioration of water quantity and quality, low returns, marketing constraints, and inability to pay debts. Around 50% of interviewed owners have suggested selling their wells to the government and are asking for fair compensation. Modern local farmers and foreign investors are continuing to buy some of the marginal income irrigated farms. This is counter to the objective of irrigation well buy-out as a means of reducing groundwater.

- Reduction: Approximately 50% of surveyed farmers supported a buy-out option. However, assuming only around 25–33% of well owners will actually sell out, a total reduction of around 15–20 MCM can be expected.

- Legal Coverage: According to Article 23 (b) of WAJ Law No. 18 of the year 1988 and Article 18 of the recently drafted and proposed groundwater monitoring regulation or bylaw, WAJ has the authority to buy out private wells, based on the fact that water resources conservation is a national priority that serves the public interest. Article 23 (b) covers the wells buy-out as purchase of land and water rights. Article 18 of the proposed bylaw covers the buy-out more explicitly.

  ***Article 23 (b), 1988 WAJ law No. 18:***
  ***The Authority is responsible for the Following: Purchase, acquire or lease properties, land and the related easement rights and the water rights required for the various projects of the Authority, and provide a prohibited area as deemed necessary for its water and sewerage networks and the related buildings and construction.***

  ***Article 18, proposed new groundwater regulation (bylaw):***

  ***The authority has the right to appropriate, rent or immediately acquire any private well for the public benefit and to appropriate a suitable right-of-way and passage for the wells it is exploiting in accordance with the provisions of applicable laws.***

- Implementation Responsibility: On the basis of the above legal articles, MWI & WAJ are responsible for implementing the buy-out option.

➢ Proposed Action Plan: This action plan, which is designed to support the implementation of the buy-out option, includes:

- Buy-out time schedule;
- Buy-out scenarios and buy-out cost;
- Buy-out socioeconomic impacts; and
- Buy-out environmental impacts.

***Buy-out schedule***

A schedule for the minimum and maximum buy-out amounts of 15 MCM (option 1) and 20 MCM (option 2) is proposed (Table 1 and Figure 11). The schedule allows 16 months, September 2001–December 2002, for guaranteeing the buy-out funds and preparing the administrative and legal framework for its implementation. The buy-out starts in 2003 and spreads over five years, with 3 and 4 MCM each year for options 1 and 2, respectively. This would lead to better monitoring and evaluation of the buy-out implementation, and gives the government financial flexibility.

**Table 1. Proposed Buy-Out Schedule**

| | | | | | | |
|---|---|---|---|---|---|---|
| Option 1<br>15 MCM | Buy-out year | 2003 | 2004 | 2005 | 2006 | 2007 |
| | Annual buy-out increment (MCM) | 3 | 3 | 3 | 3 | 3 |
| | Cumulative buy-out (MCM) | 3 | 6 | 9 | 12 | 15 |
| Option 2<br>20 MCM | Annual buy-out increment (MCM) | 4 | 4 | 4 | 4 | 4 |
| | Cumulative buy-out (MCM) | 4 | 8 | 12 | 16 | 20 |

***Approximate number and type of buy-out farms***

Specific buy-out farms will be known only when the buy-out process is announced by the MWI. This section presents an approximate estimation of the expected number and type of buy-out farms, based on farm characteristics of the well owners who may volunteer for the buy-out according to the RA survey sample. On the basis of the RA, around 26% of these owners have seasonal crop farms, 66% mixed farms, and 8% tree farms. This corresponds to approximately:

- 70 farms for option 1 (15 MCM): 31 seasonal farms, 35 mixed farms, and 4 tree farms; and

- 100 farms for option 2 (20 MCM): 45 seasonal farms, 50 mixed farms, and 5 tree farms.

***Buy-out scenarios and buy-out cost***

A buy-out model was prepared (Jabbarin and Chebaane, April 2001) based on farm gross income, farm investment estimation, and effects of water salinity on crop yield and land value. Four buy-out alternatives are presented for each of the above buy-out options 1 and 2. These alternatives are:

- **Alternative 1:** Present value of gross income;
- **Alternative 2:** Farm investment, including well, orchard, land, and water quality (salinity);
- **Alternative 3:** Farm investment, including well, orchard, and land but not salinity; and
- **Alternative 4:** Farm investment, including well and orchard but not land.

According to the RA sample, the expected water salinity of the buy-out wells can be summarized as follows:

**Table 2. Expected Water Salinity of Buy-Out Wells**

| Farm Type | High Salinity (Greater than 1,500 ppm; by %) | Medium Salinity (1,000–1,500 ppm; by %) | Low Salinity (Less Than 1,000 ppm; by %) |
|---|---|---|---|
| Seasonal farms | 10 | 0 | 90 |
| Mixed farms | 4 | 16 | 80 |
| Tree farms | 33 | 0 | 67 |

The buy-out values based on farm income have been calculated as the present value of future income (expressed as the gross margin), assuming that income continues at its current estimated level for the next 20 years. A discount rate of 10% has been used. A contingency factor of 25% has been added to both the investment and present value of income, to ensure that they would be attractive to farmers. The depreciated investment value was based on a 10-year depreciation period for well and orchard, in the case of tree or mixed farms.

The buy-out costs presented hereafter (Table 3 and Figure 12) are estimates only. They will be validated after the socioeconomic study is completed by the end of May 2001. These costs are based on annual incremental buy-out of 3 and 4 MCM spread over a five-year period, according to the schedule shown in Table 1.

For buy-out option 1, Table 3 indicates that the cost to reduce groundwater abstraction by 15 MCM by buying out 70 farms (31 seasonal, 35 mixed, and 4 tree farms) during five years (2003–2007) varies from JD7.0 millions based on Alternative 1 to JD15.5 millions based on Alternative 3. The cost dropped by 35% to JD10.0 millions if land is not part of the buy-out (Alternative 4) and declined only to JD14.0 millions, as expected, when salinity is accounted for (Alternative 2), since in this case most buy-out wells (farms) have good water quality.

| **Table 3. Estimated Buy-Out Cost (in Million JD) Based on Five-Year Schedule, 2003–2007** | | | | |
|---|---|---|---|---|
| **Buy-out Option** | **Alternative 1** | **Alternative 2** | **Alternative 3** | **Alternative 4** |
| Option 1, 15MCM | 7.0 | 14.0 | 15.5 | 10 |
| Option 2, 20 MCM | 9.5 | 19.0 | 21.0 | 13.5 |

Similarly, the cost of the 20-MCM reduction option, corresponding to buying out around 100 farms (45 seasonal, 50 mixed, and 5 tree farms), ranges between JD9.5–21 millions based on Alternative 1 and Alternative 3, respectively. Notice that the income-based value (Alternative 1) is only 50% of the highest investment-based value (Table 3 and Figure 12). Note, too, that the buy-out cost per dunum for Alternative 2 varies from JD471/dunum for seasonal farms to JD1,083/dunum for tree farms. This corresponds closely to actual farm sale values.

***Present value of buy-out cost***

The present value of buy-out cost, shown in Table 4, represents the amount of money that should be available by the end of 2001, assuming a 10% discount rate, to finance the five-year buy out program.

| **Table 4. Present Value of Estimated Buy-Out Cost (in Million JD)** | | | | |
|---|---|---|---|---|
| Buy-out Option | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 |
| Option1<br>115 MCM | 4.4 | 8.8 | 9.9 | 6.4 |
| Option 2<br>20 MCM | 5.9 | 11.8 | 13.2 | 8.5 |

***Recommended buy-out alternatives***

In buying out the farms, it would be difficult to use the gross income approach (Alternative 1), since it would require estimating the incomes of each farm. Most farms do not keep records on their costs. The value of the investment, on the other hand, would be easier to estimate since the investment items (wells, irrigation systems, trees, land) could be readily inspected to ascertain their value (Fitch, April 2001). The investment-based approach (Alternatives 2–4) can also accommodate well buy-out either with or without land. Therefore, the latter approach, which corresponds closely to actual farm sale prices, is recommended as a basis for calculation of well buy-out cost.

***Socioeconomic impacts***

Farm buy-out will directly affect laborers in the AZB highlands area and services related to farm input/output. The 20-MCM buy-out (option 2) will lead to a total labor loss of 2,433 jobs (686 male foreign, 763 male local, and 984 female local) and an annual total lost income of JD2.192 millions (JD1.129 million for expatriates, JD1.063 for Jordanians). Similarly, labor losses due to the 15-MCM buy-out (option 1) are 25% lower than those of option 2 (Jabbarin, April 2001).

Labor losses incurred by farm input/output related-services are estimated at around 30 jobs and 40 jobs for the 15 and 20 MCM buy-out options, respectively. Sale losses from input/output-related services are expected to amount to JD0.408 million for option 2 and JD0.306 million for option 1.

***Environmental impacts***

Buy-out is expected to reduce overabstraction and therefore enhance groundwater conservation. On the other hand, cessation of irrigated activity, from well closures, may reduce green spaces. We recommend that lands of buy-out farms should be restored to their original pastoral condition through appropriate land management.

## 3.3 Reduction of Abstraction

### 3.3.1 Limiting annual abstraction

- Objective: Control groundwater pumping by enforcing abstraction limits.

- Priority: This is a first-priority option and also a highly political option.

- Current Situation: Abstraction quotas or upper limits of 50,000 $m^3$/year, 75,000 $m^3$/year, and 100,000 $m^3$/year are imposed on irrigation well licenses issued by the WAJ after 1984 but have not been enforced. Older licenses issued by the Natural Resources Authority have no abstraction limit. A review of WAJ private well files revealed the following licensing status of the 491 irrigation wells in the Amman–Zarqa groundwater basin:

  - 46% have a 50,000 $m^3$/year license;
  - 20% have a 75,000 $m^3$/year license; and
  - 34% have no abstraction limit.

  In practice, the above quotas have not been enforced—as illustrated by the 1998 MWI abstraction data for AZB, which show that:

  - 97.6% have exceeded the 50,000 $m^3$/year limit;
  - 94.9 % surpassed 75,000 $m^3$/year; and
  - 91.7% pumped beyond 100,000 $m^3$/year.

- Reduction: The enforcement of an abstraction limit of 75,000 m3/year/well would correspond to 53% reduction of total irrigation water use, given that current mean abstraction is around 160,000 m3/year/well for the AZB highlands area. Similarly, the enforcement of an upper abstraction quota of 100,000 m3/year/well would lead to a 38% reduction of total irrigation water use. The 38% and 53% reductions would be equivalent to a reduction of around 23–32 MCM in AZB highlands irrigation water use, which is currently around 60 MCM/year, based on 1998 MWI abstraction data. If 25–30% of farms are bought out and a 5-MCM reduction is achieved via IAS, the total reduction due to limitations of well abstraction will decrease to 13–18 MCM. This will further decrease to about 10–15 MCM if 20% of farmers surpass abstraction limits and pay extra water charges. The latter percentage is expected to decrease with increases of water charges. If the 80-MCM estimated irrigation abstraction in the AZB highlands, based on RS and water crop water requirement was adopted, a higher reduction could be considered.

- Expected Benefits: Conserve and protect AZB highlands' aquifers and assist durability of the M&I water supply from groundwater from these aquifers. This relatively significant reduction of abstraction will lead to a decrease in cropped areas and therefore a decrease in agricultural production may in turn increase the price of produce, especially at the local market.

- Legal Coverage: Control of abstraction is covered in the form of water use regulation in item d) of Article 6 of the 1988 Water Authority Law, as stated earlier in the IAS legal coverage. On the other hand, Article 17 of the proposed new groundwater regulation gives the authority to the Minister of MWI to specify annual abstraction limits for each irrigation well and to request the MOA to specify the area that can be planted according to the specified abstraction limit.

  ***Article17 of proposed new groundwater regulation:***

  ***The Minister, in order to regulate abstraction from each groundwater basin within the safe yield, has the right to take all regulatory and field measures, to ask the Ministry of Agriculture to work out a crop pattern that is suitable to the specified quantities to be abstracted annually from each well, and to specify the area that can be planted.***

- Implementation Responsibility: MWI, WAJ, and MOA as per previous legal articles.

- Proposed Action Plan: Minimum and maximum abstraction reduction options of 10 and 15 MCM are proposed. The following are preliminary ideas and suggested actions, for discussion, to support the implementation of the above two options:

  ***Abstraction limit and abstraction charges***

  MWI/WAJ has the legal instruments to set abstraction limits. It is recommended that MWI/WAJ exercise their right to issue annual renewable abstraction licenses for all private wells. A preliminary analysis of abstraction limit scenarios undertaken in the socioeconomic study (Fitch, April 2001) indicates that a limit of 100,000 $m^3$ would be enough to farm only 140 dunums. According to the RA survey, the average farm size found in the survey was about 330 dunums of irrigated area and only 20% of farms are of the size of 140 dunums or smaller. Thus, with an annual limit of 100,000 $m^3$, only about 68 of the 340 farms irrigating from the Basalt/B2/A7 aquifer would have sufficient water to maintain current cropping levels.

Water user fees represent an option to assist strict license enforcement. Most farms do not earn high enough incomes to afford water charges of JD0.250 per $m^3$, which is the rate currently paid by industrial well operators. The same socioeconomic study shows that many farms could afford a block rate based on JD0.015/$m^3$ for water within 100,000 $m^3$/year/well limit, and JD0.100/$m^3$ for water above limit. Farms that are highly productive could afford to buy water above quota, but farms that grow only low-valued crops and are not efficient could not afford the high-valued water. They would either have to limit their crop area and restrict water use, or go out of business. It would, however, be their choice.

***Implementation schedule***

Reduction of well abstraction will be particularly burdensome for farmers who have made large investments in tree production. Therefore, a gradual reduction, spread over a period of four years for seasonal crop farms and eight years for tree farms, is recommended to allow growers to earn a return on their investment (Figure 13 and Table 5).

**Table 5. Proposed Irrigation Well Abstraction Reduction Schedule in MCM/year**

| Year | | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2010–2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Option 1: 10 MCM | Annual reduction | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 4 | 0 |
| | Cumulative reduction | 2 | 3 | 4 | 5 | 6 | 6 | 6 | 10 | 10 |
| Option 2: 15MCM | Annual reduction | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 5 | 0 |
| | Cumulative reduction | 2 | 4 | 6 | 8 | 10 | 10 | 10 | 15 | 15 |

***Incentives***

Enforcement of water management and environmental regulations essentially on the basis of penalties has not been successful in many parts of the world. Current international water regulations have moved from command-control approach to an incentive-based approach. Given the difficult political and socioeconomic aspects of the abstraction limit option, we highly recommend that incentives be provided to those who comply with the regulated abstraction quota, and extra charges or penalties be applied to those who do not respect the quota.

Provision should be made to include incentives in the new proposed groundwater management bylaw. Ideas about generation of funds to pay for incentives are described in Section 5.

***Monitoring***

The irrigation wells metering program needs to be strengthened to assist the enforcement of limitation of abstraction quota. Recommendations about monitoring of abstraction are also described in Section 5.

***Socioeconomic impacts***

Pumping reductions due to abstraction limits will directly affect laborers in the AZB highlands and services related to farm input/output. The 15-MCM abstraction reduction (option 2) will lead to a total labor loss of 1,824 jobs (514 male foreign, 572 male local, and 738 female local) and an annual total lost income of JD1.644 million, with JD0.846 million for expatriates and JD0.798 for Jordanians. Similarly, labor losses due to the 10-MCM abstraction reduction (option 1) are 33% lower than those due to option 1 (Jabbarin, April 2001).

Labor losses incurred by farm input/output-related services are estimated at 20 and 30 jobs for the 10- and 15-MCM reduction options, respectively. Sale losses are expected to amount to JD0.306 million for the 10-MCM reduction and JD0.204 million for the 15-MCM curtailment.

***Environmental impacts***

Limitation of annual abstraction is expected to reduce overabstraction and therefore enhance groundwater conservation. On the other hand, reduction of irrigated area as a result of curtailment of annual abstraction may result in reduction of green spaces. We recommend that lands that would no longer be irrigated should be restored to their original pastoral condition.

### 3.3.2 Limiting cropped area

Farmers have suggested this option as an alternative to limitation of abstraction quota.

- Objective: Control groundwater pumping on the basis of reduction of cropped area.

- Priority: This is a third-priority option and also a highly political option.

- Reduction: Beginning in the early 1990s, most new agricultural well licenses specified a limit of 100 dunums as allowed irrigated area. Areas of 100 and 200 dunums are acceptable upper size limits of seasonal crop farms and tree farms, respectively. This corresponds to a 50% reduction of cropped area, given that the current average size farm in the highlands is around 200 and 400 dunums for vegetable and tree farms, respectively. Only around 20–35% crop area reduction, from those 70% of farms remaining after buy-out, corresponds to a 15–25% reduction of current total cropped area, and therefore an abstraction reduction of around 10–15 MCM.

- Expected Benefits: Conserve and protect AZB highlands' aquifers and assist durability of M&I water supply from groundwater from these aquifers. This level of cropped area reduction, ranging between 15–25% of total irrigated area, will lead to a decrease of agricultural production, which in turn may increase the price of these produce, especially at the local market.

- Legal Coverage: Control of irrigated area is covered in the form of water use regulation in item d) of Article 6 of the 1988 Water Authority Law, as stated earlier in the IAS legal coverage. On the other hand, limitation of maximum irrigated area is covered in Article 17, shown above, and Article 40, item 3, of the proposed new groundwater regulation.

  ***Article 40 of the proposed new groundwater regulation:***

  ***The owner of any well that has been licensed, drilled and tested in accordance with these Regulations must get, before using the well, an abstraction license issued by the Minister after the prior approval of the Council. Such a license shall provide for the conditions that should be observed by the licensee. Such conditions shall specifically include, but not be limited to, the following:***

  ***Item (3): The limitation of the maximal area allowed to be irrigated from the licensed well for agricultural purposes.***

- Implementation: Limiting the total area irrigated, rather than controlling the cropping pattern, might serve to limit water abstraction somewhat. This is less direct than controlling water use through metering, but it would be more time consuming and would probably be no easier to implement legallythan the metering system. If the government should decide to limit the total crop area, this should not be viewed as a substitute for metering and license restrictions (Fitch, April 2001).

### 3.4 Exchange Groundwater with Treated Wastewater

- Objective: Exchange part of groundwater use in highlands' irrigated agriculture with treated wastewater from As Samra to reduce overabstraction and assist mainly the durability of M&I water supply from the AZB highland aquifer system.

- Priority: First-priority option, which is addressed jointly by both components of the WRPS project.

- Current Situation: Well owners in the nearby Dulayl and Hashimiyah areas are experiencing problems with water table decline and water quality deterioration owing to increasing salinity. If pumping continues as is, around 70% of wells in the HDH area are expected to dry up during the coming 5–15-year period (MWI/ARD, May 2001). However, this area is the closest to the As Samara plant and requires the least lift in elevation, compared with the rest of the irrigated farms in the AZB highlands, and appears to provide ideal candidates for recycled water reuse. Moreover, the RA survey and RS analysis found that farms in the HDH area have a far heavier concentration in tree crops than Mafraq, and almost 80% of these are olive trees, which adapt to treated wastewater. The Dulayl area is the center of part of a significant number of dairy farms and is already a significant producer of forage (alfalfa, 5% of rotation), which is ideal for treated wastewater reuse. Although much of the forage for these farms has been imported from nearby areas in Saudi Arabia, the Saudi government has recently placed restrictions on exports of such forage. Thus, the dairies require local forage supplies.

- Reduction: On the basis of the size and cropping pattern of irrigated farms in the HDH area (Figure 14A) and the potential for Hashimiya industries, essentially the power plant and oil refinery, to exchange groundwater with recycled water, 10–15 MCM is a reasonable range of potential treated wastewater reuse in the area. Around 10 MCM are assumed for irrigation and 5 MCM for industry.

- Expected Benefits: Provide highlands'irrigated agriculture with an alternative water supply in exchange for fresh groundwater abstraction to assist recovery of water level in AZB highland aquifers, in the HDH area.

- Legal Coverage: Treated wastewater reuse is not covered by WAJ and MOA laws and regulations, but is mentioned in the 1998 wastewater policy document.

  ***The 1998 wastewater policy considers recycled water as an integral part of the Kingdom's water balance and states that recycled water should be considered a water resource. As a resource its use is to be planned within adopted specifications. Priority is to be given to its careful use for irrigation purposes.***

- Implementation Responsibility: MWI, WAJ, and MOA.

- Economic Feasibilty: The economic feasibility study carried out by Willis Shaner (MWI/ARD, Nov. 2000) shows that it would not be economically viable to use recycled water from the As Samra plant in the AZB highlands if farmers were to pay for capital or operating costs of water conveyance. However, economic viability would also depend on both the value placed on conserved groundwater in the highlands and on the costs of disposing of the effluent downstream. The cost of supplying pressurized recycled water to farmers in the Dulayl and Hashimiya area is estimated to be JD0.380/m3. The recent socioeconomic study (Fitch, April 2001) indicated that the latter cost, which includes investment and O&M, is less than the present value of the opportunity cost, which is JD0.424/m3, including only investment cost. This means that the value of the groundwater saved is greater than the cost of supplying the treated wastewater. Therefore, it would be feasible to convey As Samara recycled water to farms in the HDH area. Economic analysis of exchange of groundwater industrial use with recycled water shows that this option is viable. More details are presented in the Water Reuse Action Plan.

- Proposed Actions: The preliminary proposed reuse for HDH starts in 2005, assuming that the As Samara new wastewater treatment plant will be operational at this time, with 10 MCM followed by an additional 5 MCM in 2010 (Figure 14B). Amendment of WAJ and MOA regulations to include treated water reuse is also recommended.

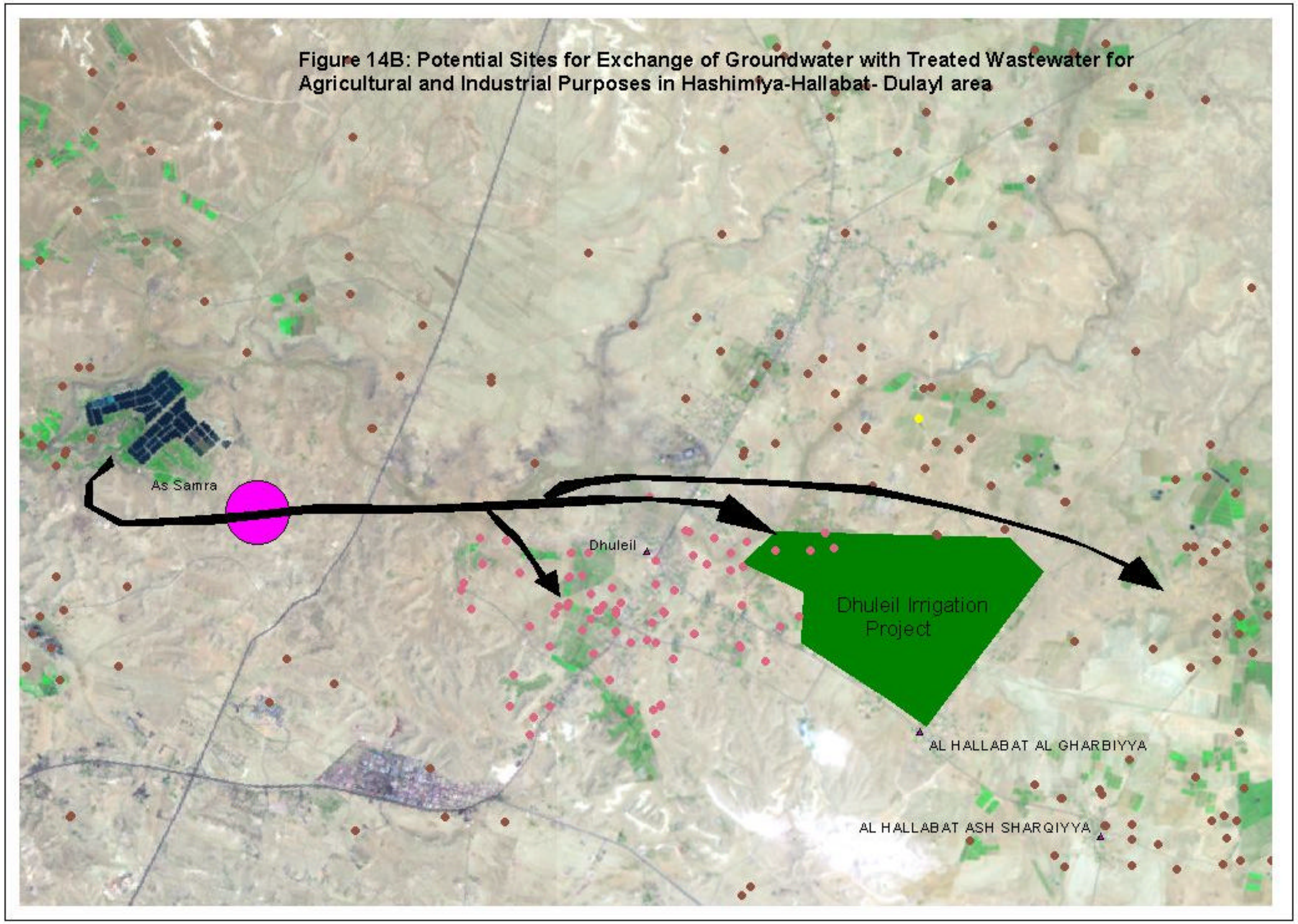



Figure 14B: Potential Sites for Exchange of Groundwater with Treated Wastewater for Agricultural and Industrial Purposes in Hashimiya-Hallabat- Dulayl area

***Socioeconomic impacts***

Exchange of freshwater with treated wastewater in HDH will have a positive socioeconomic impact. It will save agricultural returns, jobs, and services otherwise lost in case the aquifer dries up in the area. The 10-MCM exchange of groundwater irrigation use with recycled water will save 1,216 jobs (343 male foreign, 381 male local, and 492 female local) and an annual income of JD1.096 million, with JD0.564 million for expatriates and JD0.532 for Jordanians (Jabbarin, April 2001).

***Environmental impacts***

Exchange of freshwater with treated wastewater is expected to reduce overabstraction and, therefore, enhance groundwater conservation. It would also keep the agricultural land, otherwise lost in case of the aquifer drying up in the HDH area, in production. However, treated wastewater use may have negative public health effects and increase groundwater contamination, as a result of return irrigation, if not treated and managed according to appropriate standards. More details about water use standards are presented in the Water Reuse Action Plan.

## 3.5 M&I Pumping Reduction

M&I reduction includes two components:

- UFW Component: Resulting from reduction of the physical component (leakage) of the Unaccounted for Water (UFW) as a result of rehabilitation of water supply networks in areas served from AZB highlands aquifers. In other words, the current efforts by WAJ and Lyonaise des Eaux Management-Amman to reduce leakage should be reflected in reductions of abstraction in highly overexploited groundwater basins such as the AZB.

- Disi-Wehda, Zara Mai'n, AZB Brackish Water Component: Consisting of replacing part of the AZB highlands-pumped M&I water supply with water from Disi and Wehda dam.

  ***Note that the analysis of M&I water use in the AZB planned in the January 2000 first-year work plan (Activity 3.4) has been covered in part in the Study of Water Use and Users (MWI/ARD, January 2001). It is also covered in details by the JICA Water Resources Management study (MWI/JICA, January 2001 and May 2001).***

- Objective: Reach safe yield abstraction from the AZB highlands aquifers to ensure durability of M&I water supply from these aquifers.

- Priority: This is a second-priority option since, owing to current shortage of supply, this option would be considered if alternative sources of drinking water supply such as Disi, Wehda, Zara-Main, and AZB brackish water are made available.

- Reduction: According to specialists of the UFW project, UFW due to leakage or physical losses is approximately 30% in Greater Amman and 35% in Zarqa (WAJ/JICA, 2001). M&I groundwater abstraction from AZB basalt/ B2-A7 system is around 62.8 MCM. The reduction of physical losses to the 15% target, via rehabilitation of the water supply network, as indicated in the Japanese International Cooperation Agency (JICA) Water Resources Management study (October 2000) would correspond to saving an equivalent of 10 MCM from the current basalt/B2-A7 abstraction. The other current effort made by USAID–WIPEA project is expected to reduce M&I water savings by reducing water wastage by large private and public consumers such as hotels and hospitals. A minimum total reduction of 10 MCM would be expected from both the UFW component and M&I water savings. Additional reduction of 20 MCM is possible through substitution by proposed new water supply from the future sources such as Disi, Wehda, Zara-Main, and AZB brackish water, in order to reduce current abstraction to safe yield of the B2-A7/Basalt, the AZB highlands major aquifer system.

- Legal Coverage: There is no provision in the Water Authority Law No. (18) of 1988 or Groundwater Monitoring Regulation No. (26) of 1977. However, there is an indirect provision in Article 23 of the proposed new groundwater regulation, which refers to the reduction of overpumping to restore the natural balance of the groundwater basin.

  **Article 23 of the proposed new groundwater regulation states that:**

  ***The Authority has the right to declare certain zones as over-pumped or polluted and to take measures that can stop such over-pumping or pollution. These measures include the rationalization or reduction of abstraction so that the over-pumping or pollution can be stopped and the natural balance of groundwater basin can be restored.***

- Implementation Responsibility: MWI & WAJ.

- Proposed Actions: Gradual reduction, spread over a five-year period, starting in 2005. A total reduction of 10 MCM from UFW and M&I water saving component and 20 MCM from other sources such as Disi, Wehda, Zara-Main, and AZB brackish water should be achieved by 2010, as shown in Table 6 and Figure 15.

**Table 6. Proposed M&I Abstraction Reduction Schedule in MCM/Year**

| Year | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| UFW 10 MCM | Annual reduction | 2 | 2 | 2 | 2 | 2 | 0 |
| | Cumulative reduction | 2 | 4 | 6 | 8 | 10 | 10 |
| Disi-Wehda 20MCM | Annual reduction | 3 | 3 | 3 | 4 | 4 | 4 |
| | Cumulative reduction | 3 | 6 | 9 | 12 | 16 | 20 |

A summary of reduction (Figure 16) and characterization of each option, indicating the level of priority of each option and its level of cost and difficulty of implementation, legal coverage, and institutional responsibility, is illustrated in Table 7 and Figure 16.

**Table 7. Groundwater Management: Summary of Results from Preliminary Options Assessment**

| Description of Option | Expected Reduction (MCM/year) | Ranking of Overall Priority | Ranking According to Least Cost | Ranking According to Least Difficulty | Expected Benefits | Legal Aspects | Institutional Responsibility | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| Irrigation advisory | 5 | 1 | 1 | 2 | -JD3000/well (energy)<br>-Increase in production<br>-GW conservation<br>-Durability of M&I supply | Indirectly covered | MWI & MOA | Difficulties of institutional establishment and sustainability |
| Wells buy-out | 15–20 | 1 | 3 | 1 | -GW conservation<br>-Durability of M&I supply | Covered in WAJ Law and suggested Bylaw. | MWI & WAJ | Unemployment and associated impacts |
| Limiting abstraction and/or cropped area | 10–15 | 1<br>3 | 2 | 3 | -GW conservation<br>-Durability of M&I supply | Covered in WAJ Law and suggested Bylaw. | MWI, WAJ, MOA | Needs intensive monitoring and management |
| Exchange groundwater with recycled water | 10-15<br>(10 for irrigation and 5 for industrial) | 1 | 4 | 2 | -GW conservation<br>-Durability of M&I supply | Not directly covered in WAJ Law or Bylaw, but mentioned in (wastewater policy document-1998). | MWI, WAJ, MOA | Cropping pattern changes<br>Public health and environmental concerns |
| M & I Pumping reduction | 30<br><br>(10 UFW and M&I Water use saving, 20 replaced by other supply sources such as Disi-Wehda, Brackish water) | 2 | 5 | 4 | -GW conservation<br>-Durability of M&I supply | Not directly covered, but articles in the law or Bylaw Deal indirectly with this issue. | MWI & WAJ | Difficult to implement given high priority of municipal demand and dependability on implementation of other water supply projects such as Disi and Wehda dam |

## 4. POTENTIAL SCENARIOS FOR GROUNDWATER USE REDUCTION

The identified groundwater use reduction options, discussed in Section II, were also grouped in four scenarios representing possible ways to implement these options. The scenarios were designed to assist decision-makers and stakeholders to move gradually toward a sustainable abstraction from the highland aquifers, starting with a minimum reduction of 30 MCM for scenario 1, which corresponds to a target planned abstraction of 125 MCM, and progressing to a maximum reduction for scenario 4, which brings abstraction down to the 70-MCM safe yield level, as illustrated in Table 8 and Figure 17. Table 8 shows groundwater abstraction and proposed reduction over 20 years, starting in 2001 and ending in 2020. Groundwater abstraction starts with 145 MCM in 2001, which includes around 63 MCM of M&I, around 2 MCM for pastoral use, and 80 MCM for irrigation. Note that the irrigation water use was adjusted from 60 (1988 MWI database) to 80 MCM as mentioned in Section II. By 2002 the total abstraction will reach 155 MCM, considering a 10-MCM additional pumping from the WAJ "corridor" wellfield. From 2003 to 2020, the planned abstraction will be equal to 155 MCM minus the annual reduction, which is described hereafter for each scenario.

- **Scenario 1**: Groups three management options—IAS (5 MCM), minimum buy-out (15 MCM), and minimum abstraction limit (10 MCM). Total reduction (30 MCM) comes entirely from irrigation use.

- **Scenario 2**: Groups three management options—IAS (5 MCM), maximum buy-out (20 MCM), and maximum abstraction limit (15 MCM). Total reduction (40 MCM) comes entirely from irrigation use.

- **Scenario 3**: Groups four management options—the three options of scenario 2 and the reuse option for HDH, which starts in 2005 with 10 MCM followed by an additional 5 MCM in 2010. Part of the total reduction of 55 MCM comes from irrigation use (40 MCM) and the rest from reuse (15 MCM).

- **Scenario 4**: Groups all the five management options—the four options of scenario 3 and the M&I option. This scenario corresponds to a total groundwater use reduction of 85 MCM, which balances the planned abstraction in 2020 with the safe yield (70 MCM) of groundwater in the AZB highlands.

The maximum level of reduction (Scenario 4) represents around 63% and 55% curtailment of groundwater use for the irrigation and M&I sectors, respectively. This would correspond to no reduction of M&I water supply and a 50% reduction for irrigation water allocation, considering the exchange of groundwater use with recycled water and the savings due to the rehabilitation of the M&I water supply network.

**Socioeconomic Impacts**

Direct labor losses were estimated for each scenario. Note that the exchange of groundwater with treated wastewater (reuse option) and the M&I reduction options have no impacts on labor losses. Thus, scenarios 2, 3, and 4 are expected to have the same effect on labor.

Figure 18 indicates that the total foreign labor jobs lost varies between 694 for scenario 1 to 969 for scenario 2. Male Jordanian labor will lose 981 jobs in scenario 1 and 1,371 jobs in scenario 2, and female Jordanian labor will incur the highest losses, amounting to 1,400 jobs in scenario 1 and 1,960 for scenario 2. In addition, labor losses incurred by farm input/output-related services is estimated at 50 and 70 jobs for scenarios 1 and 2, respectively.

Lost income for Jordanians varies between JD1.431 million in scenario 1 (Figure 19) and JD2.001 millions in scenario 2. On the other hand, foreign labor lost jobs will correspond to a savings of foreign hard currency equivalent to JD1.262 million in scenario 1 and JD1.767 million in scenario 2. In addition, sales loss incurred by farm input/output-related services is estimated at JD0.545 and JD0.763 million for scenarios 1 and 2, respectively.

| Table 8. Summary of Groundwater Use Reduction Scenarios, AZB Highlands Aquifer System | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenarios** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010-2020** | **Comments** |
| **Scenario1** | | | | | | | | | | | IAS, Min Buy-out, Min Abstraction Limit |
| IAS | 0 | 0 | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | |
| Buy-out | 0 | 0 | 3 | 6 | 9 | 12 | 15 | 15 | 15 | 15 | |
| Abst/Crop | 0 | 0 | 2 | 3 | 4 | 5 | 6 | 6 | 6 | 10 | |
| Total Reduction: Irrigation | 0 | 0 | 6 | 11 | 16 | 21 | 26 | 26 | 26 | 30 | |
| Planned Abstraction | 145 | 155 | 149 | 144 | 139 | 134 | 129 | 129 | 129 | 125 | |
| **Scenario 2** | | | | | | | | | | | IAS, Max Buy-out, Max Abstraction Limit |
| IAS | 0 | 0 | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | |
| Buy-out | 0 | 0 | 4 | 8 | 12 | 16 | 20 | 20 | 20 | 20 | |
| Abst/Crop | 0 | 0 | 2 | 4 | 6 | 8 | 10 | 10 | 10 | 15 | |
| Total Reduction: Irrigation | 0 | 0 | 7 | 14 | 21 | 28 | 35 | 35 | 35 | 40 | |
| Planned Abstraction | 145 | 155 | 148 | 141 | 134 | 127 | 120 | 120 | 120 | 115 | |
| **Scenario 3** | | | | | | | | | | | IAS, Max Buy-out, Max Abstraction Limit, Reuse |
| IAS | 0 | 0 | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | |
| Buy-out | 0 | 0 | 4 | 8 | 12 | 16 | 20 | 20 | 20 | 20 | |
| Abst/Crop | 0 | 0 | 2 | 4 | 6 | 8 | 10 | 10 | 10 | 15 | |
| Total Reduction: Irrigation | 0 | 0 | 7 | 14 | 21 | 28 | 35 | 35 | 35 | 40 | |
| Reuse | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 15 | Starting 2005 in Dulayl-Hashimiyah |
| Total Reduction | 0 | 0 | 7 | 14 | 31 | 38 | 45 | 45 | 45 | 55 | |
| Planned Abstraction | 145 | 155 | 148 | 141 | 124 | 117 | 110 | 110 | 110 | 100 | |
| **Scenario 4** | | | | | | | | | | | IAS, Max Buy-out, Max Abstraction Limit , Reuse, M&I (rehab), M&I (Disi-others) |
| IAS | 0 | 0 | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | |
| Buy-out | 0 | 0 | 4 | 8 | 12 | 16 | 20 | 20 | 20 | 20 | |
| Abst/Crop | 0 | 0 | 2 | 4 | 6 | 8 | 10 | 10 | 10 | 15 | |
| Total Reduction: Irrigation | 0 | 0 | 7 | 14 | 21 | 28 | 35 | 35 | 35 | 40 | |
| Reuse | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 15 | Hashimiyah-Dulayl-Hallabat Area |
| M&I (rehab) | 0 | 0 | 0 | 0 | 2 | 4 | 6 | 8 | 10 | 10 | |
| M&I (Disi-others) | 0 | 0 | 0 | 0 | 3 | 6 | 9 | 12 | 16 | 20 | |
| Total Reduction: M&I | 0 | 0 | 0 | 0 | 5 | 10 | 15 | 20 | 26 | 30 | |
| Total Reduction | 0 | 0 | 7 | 14 | 36 | 48 | 60 | 65 | 71 | 85 | |
| Planned Abstraction | 145 | 155 | 148 | 141 | 119 | 107 | 95 | 90 | 84 | 70 | |

# 5. ACTIONS TO SUPPORT IMPLEMENTATION OF MANAGEMENT PLAN

The following actions are needed to support the implementation, monitoring, and evaluation of the groundwater management plan:

- Enforce water use laws and regulations, with emphasis on illegal drilling and illegal water sale;
- Amend current laws and regulations to explicitly cover existing gaps, related to the implementation of groundwater management options and supporting tools;
- Establish the institutional framework for participatory basin-level integrated management;
- Monitor management of AZB-shared groundwater resources;
- Establish a GMF;
- Form a Groundwater Management Consultative Committee (GMCC);
- Restructure current marketing system;
- Enhance monitoring and information management;
- Identify and develop alternative water sources;
- Establish a water user educational and public awareness program; and
- Strengthen capacity building in data analysis and water management.

## 5.1 Illegal Drilling and Illegal Water Sale

- Priority: First priority, immediate.

- Current Situation: Illegal drilling in AZB is very limited. According to MWI sources, illegal wells represent around only 1% of total irrigation wells. The low rate is mainly due to risk of losing (high capital cost) deep highlands' wells as a result of well closure. The total illegally drilled wells, in other basins, exceeds 500. This issue has been a major concern of MWI, the Parliament, and the irrigation committee of the Economic Consultative Council (ECC). Illegal water sale was noticed during the RA field visits.

- Implementation Responsibility: MWI & WAJ.

- Proposed Actions: Illegal drilling should be stopped immediately. Illegal water sale needs to be identified and also stopped. Private water sale for irrigated agriculture needs to be disallowed. Water sale by well owners should not be allowed in overabstracted areas. The ban on new well permits for irrigated agriculture should be enforced.

## 5.2 Institutional Reform and Basin-Level Management

- Priority: First priority.

- Current Situation: Possible overlap of responsibility between MWI and MOA in implementation of options such as IAS, abstraction limit, and exchange of groundwater use with treated wastewater.

- Proposed Action: Establish and institute decentralized integrated-participatory water management using AZB groundwater basin as management unit. The recommended groundwater management approach will be based on participation of stakeholders. This approach could be replicated and applied to other groundwater basins in the Kingdom. This action was discussed with MWI and stakeholders and has been endorsed by stakeholders during the June 2001 stakeholders meeting.

### 5.3 Management of AZB-Shared Groundwater System

- Priority: Second priority, for the time being.

- Current Situation: Groundwater development on the Syrian side of the AZB is recent. It has been increasing because there is no ban on drilling, but is still limited (Figure 20). A small number of Jordanian sharecroppers moved their operation to the Syrian side in search of better water quality and virgin soil, as indicated in the "Study of Water Use and Users in the Northeastern Amman–Zarqa Basin" (MWI/ARD, January 2001).

- Proposed Actions: Monitor groundwater development on the Syrian side. RS is recommended as a monitoring tool for current and future groundwater development. Negotiation with Syria is not recommended at this stage, since groundwater development on the Syrian side is not significant—as illustrated in the August 1999 Landsat satellite image shown in Figure 20.

### 5.4 Creation of an AZB Groundwater Management Fund

Funding of services-related activities such as irrigation advisory and monitoring are generally scarce. For this reason most extension and monitoring programs struggle to sustain. Implementation of difficult options such as reduction of abstraction limits has to be based on incentives and compensation, a win–win situation, as clearly voiced during discussion with farmers and as recommended during the June 2001 stakeholders meeting.

- Objective: A Groundwater Management Fund (GMF) is recommended to cover:

  - Long-term IAS funding, after pilot program;
  - O&M of private wells metering monitoring program; and
  - Incentives and compensation for water users who comply with regulations.

- Priority: First priority.

- Sources of Funding: The GMF could be generated from the following sources:

  - Irrigation groundwater water conservation fee for all water pumped within abstraction limit;
  - Irrigation abstraction charges for each cubic meter surpassing the allowed abstraction limit;
  - Domestic groundwater use conservation fee 3% of water bill from municipal consumers;

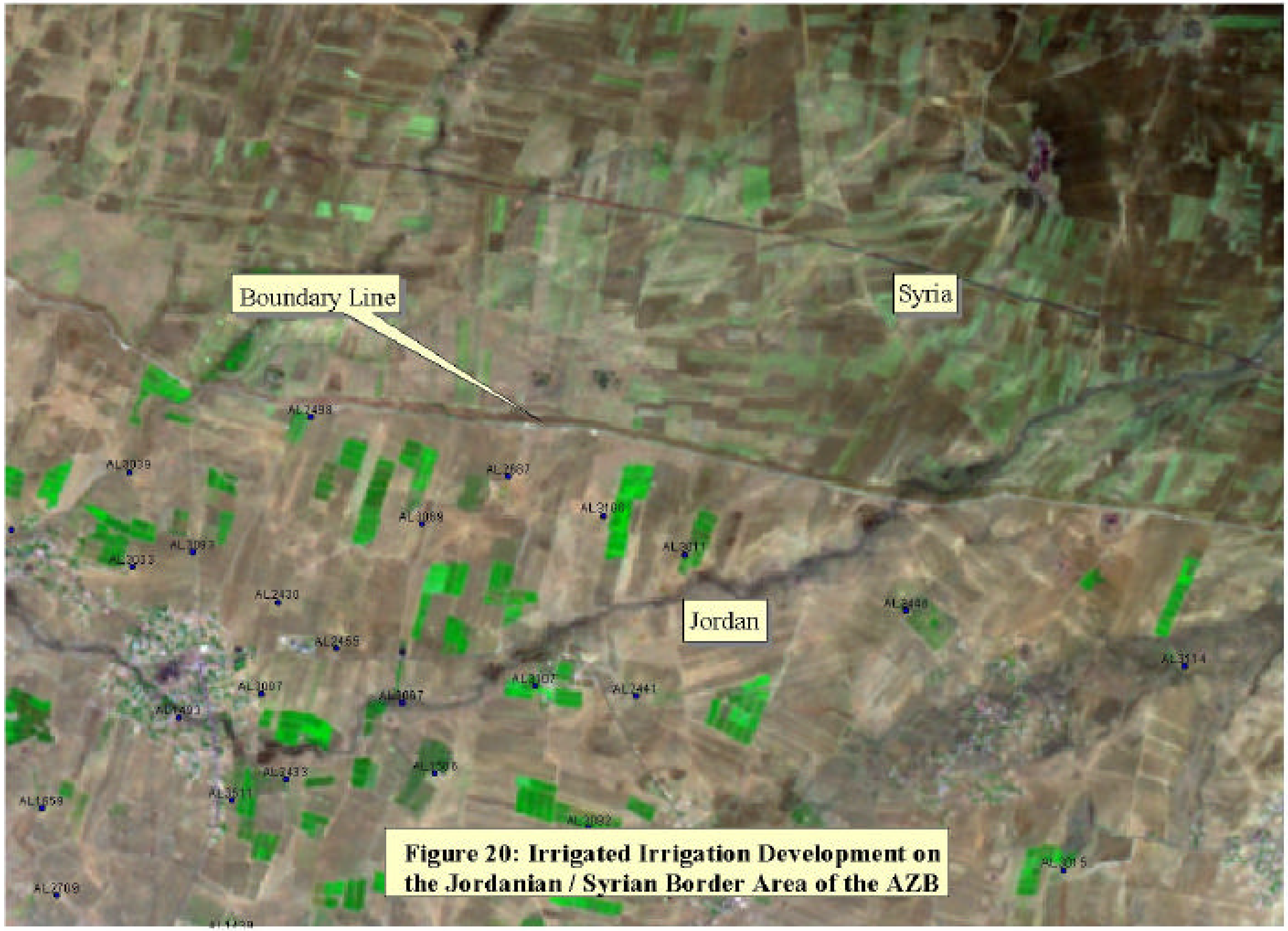



**Figure 20: Irrigated Irrigation Development on the Jordanian / Syrian Border Area of the AZB**

- Industrial–commercial water use, from WAJ network, conservation fee 5% of water bill; and
- All industrial private wells charges: The total amount (100%) of water charges collected from owners of private industrial wells.

A preliminary estimate of GMF income is expected to be approximately JD2.5 millions/year. Among the advantages of these funds is that it is generated by collaborative contribution of all water users for the noble objective of durability of the supply for the domestic and agricultural sector. The benefits of durability of the source of supply from M&I sectors outweigh their minimal fee contribution, given that the depletion of these sources would mean paying much more expensive alternative supplies from other sources such as Disi, brackish water, desalination, and so forth. On the other hand, for the agricultural sector, the fund is intended to assist in providing incentives for groundwater use reduction.

### 5.5 Stakeholder Participation

- Priority: First priority.

- Stakeholder Participation: Stakeholders have been meaningfully engaged in exploring and discussing groundwater use reduction options, with principal emphasis on curtailment of irrigated agriculture water use. Groundwater use reduction is highly political. The WRPS approach in dealing with this sensitive issue is to move purposefully toward a practical and meaningful water use reduction solution with involvement of water users and decision-makers. WRPS engaged a wide spectrum of water users, including well owners, tenants, and sharecroppers. Well owners of various backgrounds—Bedouins, investors, community leaders, farmers' union representatives, Parliamentarians, former Army officers, and former high government officials—have expressed their concerns and voiced their opinions and suggestions about curtailment of groundwater abstraction. Well owners have shown high levels of cooperation and willingness to be part of the collaborative water management process. This was instrumental in the formulation of potential actionable options and in building scenarios to evaluate the socioeconomic impacts of these options. Informal discussions with relevant members of the ECC Irrigation Committee, the Director of NCARTT, and the head of Soil and Irrigation Department at MOA were conducted in February 2001 to present the project objectives.

  A one-day stakeholders meeting was held on June 11, 2001 to further discuss with stakeholders and screen the various groundwater management options and scenarios and the practical actions to support their implementation. The meeting involved more than 80 participants, including community leaders, specific farmers, the head of the National Farmers Union and its representatives in the AZB and Jordan Valley (JV), farm managers, representatives of the Governorate of Mafraq, government agencies, and independent institutions. Two groundwater working groups were formed to discuss the five options, the GMF, and the GMCC. All five management options were endorsed. Concerns about social and environmental (desertification) impacts of buy-out, socioeconomic and environmental impacts of limiting abstraction, and impacts of water reuse on marketing and environment were expressed. The GMCC and GMF were strongly supported. Among the suggestions for implementation of the action plan made by the groundwater working groups were the establishment of alternative activities and projects for those who opt for well buy-out, ensuring fair buy-out, elaborating clear legislation to support GMF, and promoting water harvesting.

### 5.6 Formation of a Groundwater Management Consultative Committee

A GMCC is recommended to support implementation of the groundwater management actions. A note on forming a Groundwater Management Consultative Committee (GMCC) was presented to MWI/USAID in December 2000, and also included in the "Study of Water Use and Users in the Northeastern Amman–Zarqa Basin" (MWI/ARD, January 2001). The June 2001 stakeholders' workshop recommended the formation of the GMCC. Well owners suggested that a private sector representative should head the committee.

### 5.7 Cropping Patterns and Marketing

- Priority: Third priority.

- Current Situation: More than 60% of crops in AZB highlands are trees, about 40% of which are olives. Vegetable crops are limited to a few traditional crops such as tomatoes, watermelon, and cabbage/cauliflowers. Vegetable production, especially tomatoes, is in surplus and therefore often sold at uneconomical prices. There is a clear tendency toward replacing fruit trees with olive trees. The local marketing system is traditional and the export market is limited, especially after reductions of exports to the Gulf region. Export of high water consumption and marginal value crops such as tomatoes means uneconomical export of virtual water. The economic analysis of crop returns in the AZB highlands (Fitch, April 2001) revealed, as indicated earlier, that olives have currently negative net profit, mainly on account of immature plantations in the area. This supports a similar finding of the EEC Irrigation Committee.

- Responsibility: MOA, NCARTT for cropping patterns; MOA and private sector for marketing.

- Recommendations and Proposed Actions: The following are the recommendations of the Agricultural Marketing Analysis carried out by the groundwater management component ( Amer Jabbarin, June 2001).

  - The effectiveness of mandatory cropping patterns is questionable and their implementation is difficult; therefore we do not recommend it as a groundwater management instrument;
  - Opt for high-value/low-water requirement crops;
  - Promote export-oriented crops (cut flowers, late grapes, iceberg lettuce);
  - Restructure current marketing by establishing solid partnership between public and private sectors; and
  - Strengthen coordination and cooperation among producers.

## 5.8 Amendment of Laws and Regulations

- Priority: First priority.

- Current Situation: Results of the study on the "Legal Assessment of the Groundwater Management Recommendations in the Amman–Zarqa Basin Highlands" (MWI/ARD, April 2001) were presented in Section IV of this report for the five groundwater use reduction options. The main findings of the latter study is presented herein to summarize the legal coverage of all the groundwater management options and supporting tools and to recommend actions to address legal gaps and amendment of existing regulations.

  The following options and supporting tools are legally covered:

  - Well buy-out option (WAJ law);
  - Limiting abstraction and/or cropped area option (WAJ law and proposed bylaw);
  - Stopping illegal drilling and illegal water sales (WAJ law and suggested bylaw);
  - Mandating of crop pattern (agriculture law);
  - Managing an AZB-shared groundwater system (WAJ law); and
  - Monitoring abstraction and implementation of groundwater management option (WAJ law, existing bylaw, and proposed bylaw).

  The following items are only indirectly covered:

  - IAS option;
  - Reducing M&I pumping option;
  - Supporting management at the basin level; and
  - Role of private sector in water management.

  The supporting management tools stated below are not covered:

  - Restructuring agricultural marketing;
  - Establishing an AZB Groundwater Management Fund;
  - Forming a Groundwater Management Committee;
  - Exchanging groundwater with treated wastewater option; and
  - Incentives and compensations for compliance with regulation.

- Proposed Action: Amendment of current laws and regulations is urgently needed to explicitly cover existing gaps, related to the implementation of the following groundwater management options and supporting tools:

  - IAS option;
  - Exchanging groundwater with treated wastewater option;
  - Reducing M&I pumping option;
  - Forming a GMCC;
  - Promoting the role of the private sector in water management;
  - Supporting management at the basin level;
  - Establishing an AZB GMF;

- Incentives and compensation for compliance with regulations; and
- Restructuring agricultural marketing.

## 5.9 Monitoring and Information Management Support

### 5.9.1 Monitoring of abstraction

- Objective: Groundwater use abstraction is the most essential basic data for the groundwater water use reduction plan. Therefore, the main objective of the abstraction monitoring program is to provide the most reliable data to implement and monitor the groundwater use reduction options.

- Priority: First priority.

- Current Status: Current groundwater use monitoring is based on well meter readings and estimation based on crop area and rough applied water per dunum. As stated earlier, the RA field survey has shown that 40% of the meters are malfunctioning, and most farmers think that meters are not an adequate method for monitoring because existing meters may be tampered with.

- Findings of Metering Study: This study (MWI/ARD, June 2001) reviewed the well metering program and assessed electricity consumption and RS as alternative techniques for monitoring of groundwater abstraction.

    - Electricity consumption method: Data from the National Electricity Company was examined. It was found that electrical consumption data for the pumps in many cases include the electricity consumed by booster pumps used to pressurize the water for drip or other micro-irrigation systems and other electricity uses. This distorts the abstraction estimate unless all other uses of electricity are monitored separately, which is seldom the case. On the other hand, this method cannot be used only for all wells since only 43% of the farmers use electrical powered pumps. In addition, energy consumption per unit of water pumped changes as pump efficiency drops with wear and introduces significant variability into this method of water abstraction estimation. In summary, electrical energy consumption data should not be used to estimate groundwater abstraction for the entire AZB. It is useful only as a spot check of a limited number of individual well meter readings.

    - RS method: RS has been introduced by the WRPS project as a new technology to monitor cropped area. RS has proved to be effective at estimating basin- or subbasin-wide irrigated areas and irrigated area for individual isolated farms (Figure 21), but failed to distinguish among clustered farms. In addition, estimation of water abstraction by RS data is still dependent on theoretical crop water requirements and estimates of water use efficiency. Therefore, the Remote Sensing–Crop Water requirement method should be used only as a supporting tool to fill in water meter reading gaps.

    - Water meter reading method: On the basis of the above, the most accurate and reliable method of measuring groundwater abstraction is by water meter. Field investigations revealed that more than 95% of the water meters installed

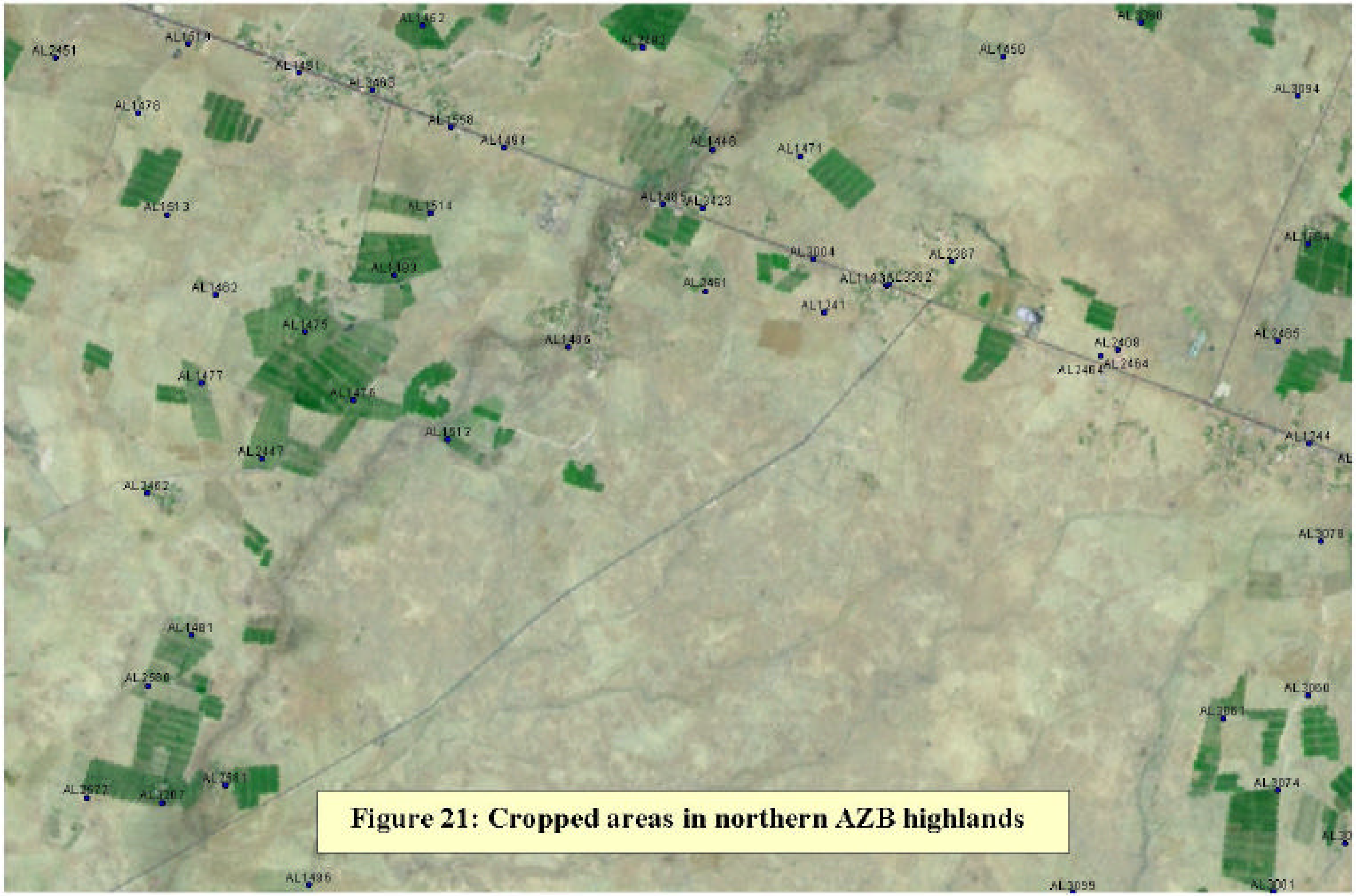


Figure 21: Cropped areas in northern AZB highlands

on private industrial wells are operational. Beside meters' being tampered with, there are two main reasons for low percentage of operational meters installed on irrigation wells:

- Only 60% of installed meters are WAJ standard meters (same as industrial meters); the rest are purchased from the local market and installed by well owners. WAJ has no spare parts for the latter meters.
- Industrial well meters have priority at the WAJ repair shop because of the high charge (JD0.250/m3) paid by industrial well users.

- Proposed Actions: The following actions are recommended to improve the monitoring of agricultural groundwater use in AZB.

  - Continue use of well meter readings, to obtain actual measurement of applied water, and supplement well meter readings with remote sensing and electricity data.
  - RS is recommended for monitoring cropped area and well buy-out, and therefore as a support tool for monitoring the implementation of groundwater management options.
  - Establish a practical program to improve and upgrade the AZB irrigation wells metering. The program includes:
    - Establishment of a meter repair and maintenance system;
    - Standardization of meters;
    - Strengthening of monitoring operation;
    - Data reporting and management; and
    - Water users education and awareness.

  The program is expected to cost around JD286,000. The cost includes the establishment of a repair/maintenance crew, the replacement/rehabilitation of meters, and training of meter readers and repair/maintenance crew. The wells buy out option may make many meters available for use on other wells to standardize the meters. The purchase of replacement meters could be done through the use of the GMF. More details about the metering program are available in the Groundwater Abstraction Metering and Monitoring report (MWI/ARD, June 2001).

### 5.9.2 Information management

- Priority: First priority.

- Current Situation: MWI has an advanced Oracle-based database system, which has most of the information relevant to the implementation and monitoring of the AZB groundwater management plan, with the exception of the well license information—especially the licensed water abstraction limits or quotas, which are available in WAJ folders. These data are essential to the monitoring of the implementation of the abstraction limit option.

- Compilation of License Data: The WRSP groundwater management team assisted WAJ and MWI in putting all AZB license information in tabulated Excel files. One member of the team will continue until the end of July 2001, inputting the rest of the license data for other groundwater basins.

- Recommended Action: Complete the electronic tabulation of the license data for all groundwater basins and transfer the electronic files to the Water Information System Database.

### 5.9.3 Upgrade of surface and groundwater monitoring networks

- Objective: The following three major objectives underlie the need for rehabilitating and upgrading the present water resources monitoring plan in the AZB:

  - Provide essential groundwater level monitoring data to understand the response of the aquifers to climate variability and water use and to define and enforce measures to implement groundwater water use management options;
  - Provide essential water quality data to assess and manage impacts of water use on groundwater quality; and
  - Provide accurate, reliable climate, precipitation, base flow, and flood flow data for the basin.

- Priority: First priority

- Current Status: A review of the surface and groundwater monitoring network was completed. It revealed that the surface water monitoring network, except in north Badia, where a flood-flow measuring station is required, is generally adequate for monitoring the implementation of the AZB groundwater management program. However, the groundwater monitoring network requires extensive rehabilitation, especially in the northeastern area.

- Achievements: The WRPS Groundwater Management Team assisted MWI in achieving the following tasks:

  - Construction of a new surface water monitoring station was in wadi Za'atari, north Badia (Figure 22).

Figure 22

- Rehabilitation (Figure 23) of seven groundwater level monitoring wells, within AZB, in the area extending from Greater Amman to Northern Badia.


Figure 23

- Maintenance of 17 water level recorders; and

- Assistance in the operation of four hydroclimate stations.

➢ Recommended Actions: The following two actions are recommended:

- Drill two proposed groundwater level monitoring wells in Northeastern Badia, as specified in the “Rehabilitation and upgrade of the Groundwater Monitoring and Wadi Flow Networks, AZB” report (MWI/ARD, June 2001); and
- Implement the recommendations of the “Rehabilitation and upgrade of the Groundwater Monitoring and Wadi Flow Networks, AZB” report (MWI/ARD, May 2001).

### 5.10 Augmentation of Supply and Resources

#### 5.10.1 Brackish water resources development

➢ Priority: First priority.

➢ Current Status: Brackish water from Zarqa group and Kurnub aquifers is a potential source of M&I for Jarash and part of the Amman area. Within the AZB, the brackish water resource consists of the lower sandstone hydraulic complex made up of the regional aquifers of the Ram Group overladen by the Zarqa Group and the Kurnub Group. There are springs that discharge from the contacts within this sandstone complex. The lower sandstone hydraulic complex is overladen in the northeastern highlands by the freshwater aquifers of the B2-A7 and Basalt. Deterioration of the freshwater aquifers as well as severe shortages of potable water, especially in the summer months, has led WAJ to look at developing brackish water resources. Reverse osmosis desalination technology has been used for treatment of brackish water from existing sources to potable standards to either augment existing distribution networks or to supply remote areas. The long-term implication is that brackish water can be an additional valuable resource for Jordan.

- Findings of Brackish Water Study: The Groundwater Management Team carried out a brackish water study (MWI/ARD, June 2001) to assess the availability and exploitation potential of brackish springs and brackish groundwater of the AZB, with emphasis on Zarqa Group and Kurnub aquifers.

  - For springs, the Team concluded that only the Abu Zigan springs (Figure 24), with a total annual discharge of 1.2 MCM, could be readily developed for M&I supply.

  - For groundwater, the Team concluded that initial yield estimates—prior to the implementation of an exploration program—are in the region of 15–30 MCM per year.

- Recommendations: The total 16.2–31.3 MCM of additional brackish water resources should assist in substituting part of the 20-MCM M&I groundwater use reduction of AZB highlands. A review of any potential water rights issues would be needed as part of a feasibility study prior to development of the Abu Zigan springs. The groundwater brackish resource requires a detailed investigation to verify and confirm the locations of exploration boreholes, to review the cost of wells, and look at the availability of suitable means of brine disposal.

### 5.10.2 Runoff recharge and water harvesting

- Priority: Second priority for recharge and first priority for small water harvesting schemes.

- Current Status: A 1-MCM capacity dam was constructed in Khaldiya in 1983 to hold runoff and enhance infiltration from the reservoir, which would benefit groundwater resources locally. The dam proved unsuccessful in enhancing recharge in the long term because of rapid siltation and the loss of water storage (Edworthy, April 2001).

  The MWI/USAID Water Quality Conservation project (WQIC) conducted an assessment of artificial recharge in Jordan and prepared detailed designs for a project in the catchments of the Wadi Madoneh and Wadi Butum. The project would involve the use of a series of wadi dams and water harvesting measures for the optimization of natural recharge (MWI, 1997a and b).

  Water harvesting came up during discussions with well owners during the RA survey (April–June 2000). Some went back to the Nebatian era where rainfall and runoff harvesting was successfully practiced in desert areas such as the Badia. A farmer showed us his own private small recharge dam. Many farmers think that the construction of harvesting and recharge schemes would solve water overabstraction in the area.

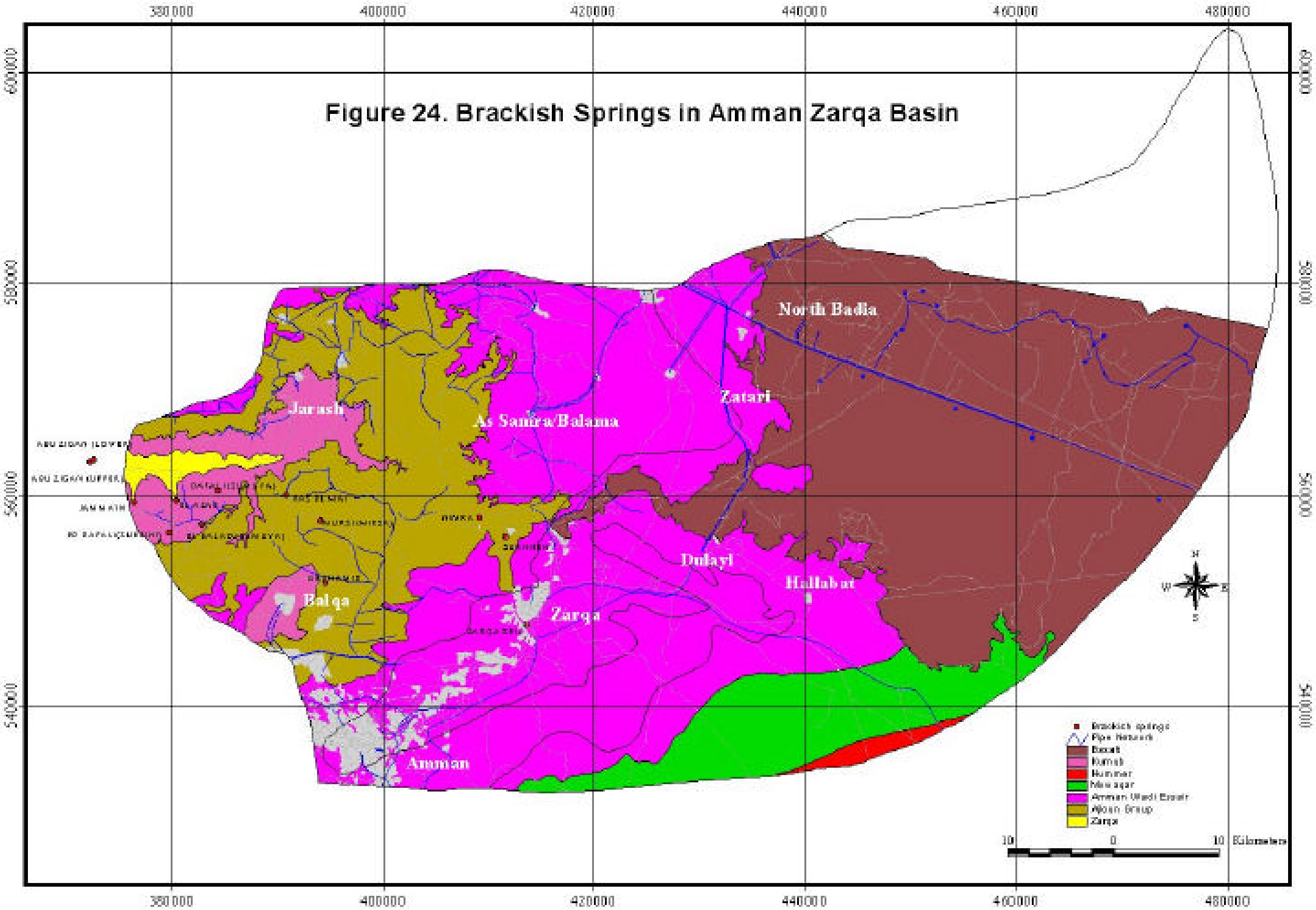



Figure 24. Brackish Springs in Amman Zarqa Basin

The water harvesting schemes may increase local direct recharge in the vicinity of the recharge structures, but this recharge would be insignificant when compared with an overabstraction over the whole AZB basin approaching 100% of the safe yield. In addition, runoff and flood-flow retention in the highlands will reduce downstream surface storage at King Talal Reservoir (KTR). Al Beit University in Mafraq is conducting research work in runoff harvesting in Al Badia.

- Proposed Actions: Carry out a pilot artificial recharge project in Wadi Madoneh, and conduct a feasibility study on the implementation of small runoff harvesting schemes in the AZB highlands area.

### 5.10.3 Treated wastewater recharge

A recent treated wastewater recharge study (Edworthy, April 2001) identified surface recharge infiltration sites in the Hallabat area (Figure 25). However, this area includes potable water supply wells. Therefore, it was concluded that recharge of treated effluent into aquifers that are used at any point for potable supply would be wholly unacceptable at present, even with comprehensive treatment and well recharge.

## 5.11 Water Users Education and Awareness

- Priority: First priority.

- Current Situation: The rapid appraisal initiated water resources and water use education in the AZB highlands. During interviews with water users, the RA team explained groundwater resources in the basin and potential effects of overabstraction on the development in the area, with emphasis on agricultural sector. Some farmers expressed the need of awareness programs to educate farmers about water conservation and water management under scarcity. The legal assessment activity (MWI/ARD, April 2001) recommended the need for educating water users on water related laws and regulations.

- Recommended Actions: An agricultural water use educational and awareness program is recommended, preferably in conjunction with the IAS. The program should include irrigation efficiency and agricultural water use under scarcity, introduction to water laws and regulations, and youth education on water use in the agricultural sector. This program will complement the ongoing Water Education & Public Information Activity project.

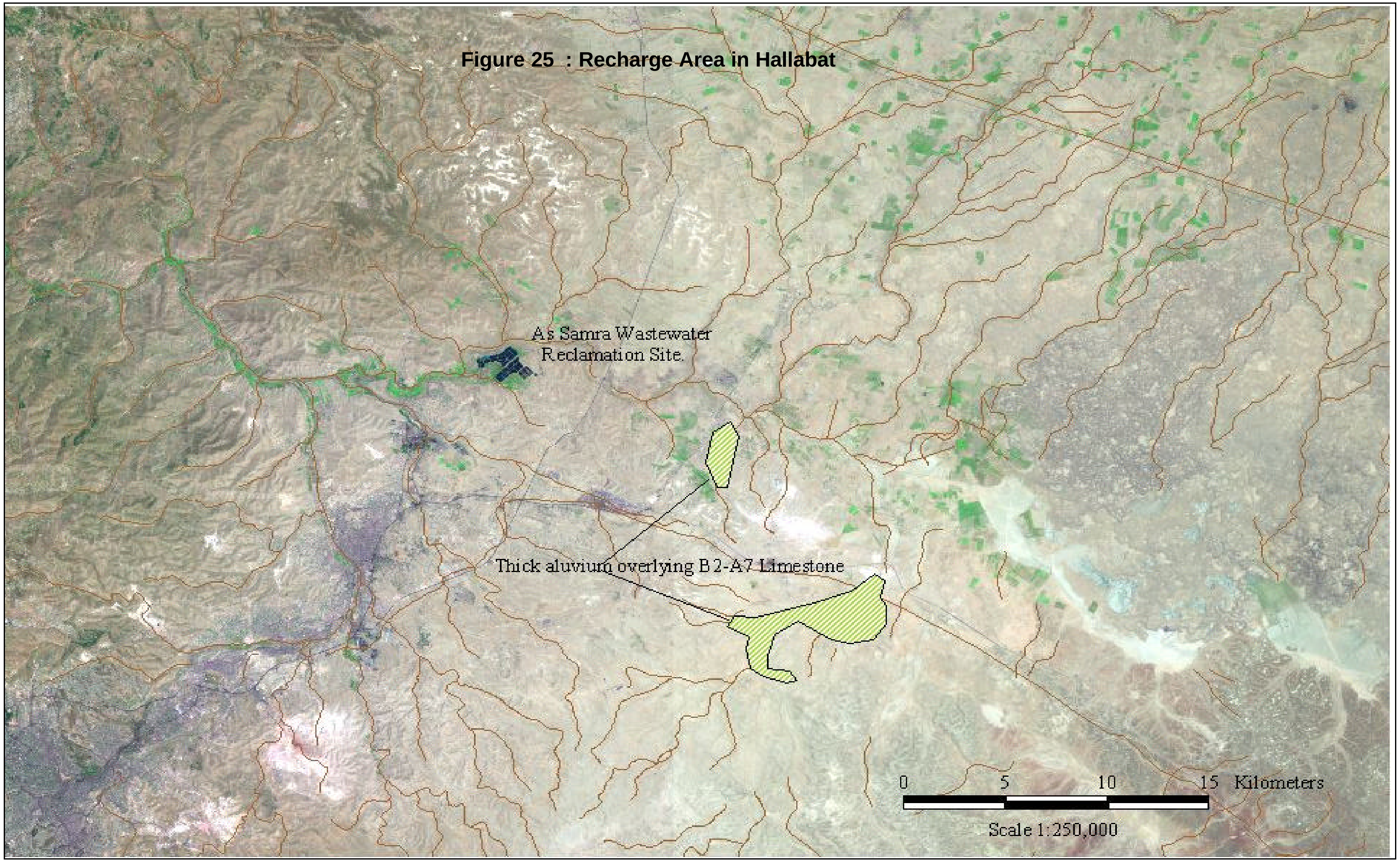



Figure 25 : Recharge Area in Hallabat

### 5.12 Capacity Building

- Priority: First priority.

- Current Status: The WRPS project organized two training programs. The first was an introduction to RS as a tool of estimation of irrigated crop area. The second covered groundwater modeling for management of AZB highlands aquifers system.

- Recommended Actions: The following four actions are recommended:

  - Carry out additional RS training;
  - Establish a geographic information system/RS Unit in MWI;
  - Strengthen private water use monitoring capability; and
  - Strengthen data analysis capability related to water resources planning and management.

# 6. CONCLUSION

Continued overpumping of groundwater in the AZB highlands over the next 20 years is projected to lead to further deterioration in groundwater quality, continuous drawdowns averaging 0.5 meters/year, and drying up of 70% of the wells in the HDH area. As a result, according to the socioeconomic study, the agricultural sector in the AZB highlands is expected to incur a total of JD52.65 million losses over the next 20 years. In addition, a 4.5–4.7% increase is expected in the local unemployment rate in the AZB highlands, which is currently around 15%. The main environmental problems foreseen as a result of the continued groundwater overexploitation are the depletion of water resources, the deterioration of water quality, the soil salinity that may lead to soil sterility, and the reduction of green spaces owing to abandonment of farms.

This report presented options and practical actions to curtail groundwater, with the objective of protection and durability of the M&I water supply. Analysis of water use and users in the highlands, and discussion with water users and other stakeholders, indicates that significant groundwater use reductions in the AZB highlands is achievable. Five reduction options were presented and characterized, and recommended actions to support the implementation of these options are defined.

The five reductions options are identified as:

- IAS (5-MCM/year estimated reduction);
- Wells buy-out (15–20 MCM/year);
- Enforcement of abstraction limit (10–15 MCM/year);
- Exchange of groundwater with treated wastewater (15 MCM/year—10 MCM for irrigation and 5 MCM for industrial use); and
- M&I Reduction: 30 MCM, with10 MCM as regained UFW resulting from reduction of physical losses due to rehabilitation of water conveyances and M&I water use saving by reducing water wastage by big industries, hotels, and households; and 20 MCM replaced by new water supplies from Disi, Wehda, Zara-Main, and AZB brackish water sources

The economic analysis shows that the IAS and buy-out are the most viable options. Costs of the IAS are estimated at JD250,000 for a five-year pilot program, and the buy-out costs would amount to JD13.2 million. Valuing the water saved at the very conservative opportunity cost of JD0.424/$m^3$ (Disi project investment excluding O&M), the present value of the water saved via IAS (5 MCM/year) over the next 20 years comes to JD11.5 million. Similarly, the present value of the water saved (20 MCM/year) via the buy-out would be around JD45.8 million.

The enforcement of abstraction limits is a politically and administratively difficult option. Reduction of well abstraction will be burdensome for farmers who have made large investments in tree production; however, with the proposed pairing of abstraction limits and abstraction charges, water user fees represent an alternative option to strict license enforcement. Most farms do not earn high enough incomes to afford water charges of JD0.250/$m^3$, which is the rate currently paid by industrial well operators. The same socioeconomic study shows that many farms could afford a block rate based on JD0.015/$m^3$ for water within 100,000 $m^3$/year/well limit, and JD0.100/$m^3$ for water above limit. Farms that are highly productive could afford to buy water above quota, but farms that grow only low-valued crops and are not efficient could not afford the high-valued water. They would either have to limit their crop area and restrict water use, or go out of business. It would, however, be their choice. Moreover, we recommend that incentives be provided to those who comply with the regulated abstraction quota, and apply extra charges or penalties to those who do not respect the quota.

The GMF would support the sustainability of the IAS and operation of the well metering program, and would provide incentives related to the implementation of the groundwater use reduction action plan. The GMFcan be generated from water conservation fees from M&I and agricultural use, water charges from private industrial wells, and overabstraction charges from agricultural water users.

The recent socioeconomic analysis indicated that (based on the preliminary economic feasibility cost estimate of JD0.380/$m^3$, including investment and O&M) the cost of supplying pressurized recycled water to farmers in the Dulayl and Hashimiya area is less than the present value of the Disi opportunity cost. Therefore, it would be feasible to convey As Samara recycled water to farms in the HDH area.

The UFW option for M&I reduction is certainly economically viable, since the rehabilitation cost is much lower than the Disi opportunity cost. The substitution of 20 MCM of M&I supply from AZB highlands groundwater with new supplies from Disi-Wehda future projects is the most costly option in the short term, but will conserve the resource for sustainable supplies to Amman for the future.

The buy-out and the enforcement of abstraction limit options are expected to hurt employment and other services related to farm input/output such as fertilizer-pesticide companies, transportation, and tomato paste companies. For instance, the 20-MCM buy-out would result in the loss of 2,433 jobs (686 male foreign, 763 male local, and 984 female local). Total lost labor income during the proposed five-year buy-out period is estimated at nearly JD2.2 million, with 1.063 million and 1.129 for local and foreign labor, respectively. Note that the foreign lost income would correspond to a savings in foreign remittances. Job losses due to enforcement of abstraction limits of 15 MCM are around 25% lower than those due to the 20-MCM buy-out.

Four management scenarios grouping more than one option were developed on the basis of priority-cost-difficulty of implementation of each option, and presented in increasing order of total reduction. Scenario 1 corresponds to a reduction of 30 MCM, which consists of 5-MCM IAS, 15-MCM buy-out, and 10-MCM enforced abstraction limit. Scenario 2 has a 40-MCM reduction corresponding to the maximum reduction of each of the latter irrigation use options. Scenario 3 corresponds to a 55-MCM reduction, which encompasses the options of scenario 3 in addition to the 15 MCM of reuse option. Scenario 4 has a total reduction of 85 MCM, including all options in scenario 3 and the 30 MCM M&I reduction.

A series of recommended actions to support the implementation of the management scenarios are also presented according to their priority. These recommended supporting actions include the enforced interdiction of illegal drilling, amendment of water use and management related laws and regulations, institutional reform and integrated basin level management, stakeholder participation and formation of groundwater management consultative committee, marketing, monitoring and information management, and water user education and public awareness. Alternative options for improving water supplies such as brackish water exploration and development to augment water supply, and recharge and water harvesting to increase water resources in the AZB are also discussed.

A one-day stakeholders meeting was held on 11 June 2001 to further discuss with stakeholders and screen the various groundwater management options and scenarios, and the practical actions to support their implementation. The meeting involved more than 80 participants, including community leaders, specific farmers, the head of the National Farmers Union and its representatives in the AZB and the JV, farm managers, representatives of the Governorate of Mafraq, government agencies, and independent institutions. Two groundwater-working groups were formed to discuss the five options, the GMF, and the GMCC. All five management options were endorsed. Concerns about social and environmental (desertification) impacts of buy-out, socioeconomic and environmental impacts of limiting abstraction, and impacts of water reuse on marketing and environment were expressed. The GMCC and GMF were strongly supported. Among the suggestions for implementation of the action plan made by the groundwater working groups were the establishment of alternative activities and projects for those who opt for well buy-out, ensuring fair buy-out, elaborating clear legislation to support GMF, and promoting water harvesting.

On the basis of the above results, we conclude that the groundwater management plan has provided the practical options of achieving groundwater use reduction in the AZB highlands through a joint effort with MWI, the water users, and other relevant stakeholders.

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